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ABSTRACT

This study was designed to formulate a predictive equation to identify community college biology students (N=420) who most probably would not succeed in science courses. A College Biology Student Survey (developed for the study), Nelson Denny Reading Test (Form-F), College Guidance Placement (CGP) Arithmetic Test, and An Inventory of Piaget's Developmental Tasks were used to obtain student background characteristics, reading/mathematics ability, and cognitive developmental level. Data collected from students in 22 biology classes indicated: more females (82%) than males (22%); a mean age of 26; racially balanced classes (49% white and 51% non-white); that 71% were single or formerly married; that 9% were at the formal level of cognitive development; a mean score of 15/25 on the mathematics test (measuring 6th-grade mathematics ability); an average 12th-grade reading level; and an average course grade of 2.7(C+). When data were analyzed using multiple regression, background characteristics and reading/mathematics ability accounted for 42% variance in cognitive development and 43% variance in achievement; cognitive development accounted for 12.8% variance in achievement; and with cognitive development as a mediating variable, background characteristics and reading/mathematics ability accounted for 22% variance in achievement. Recommendations were made on the predictive equation formulated from these results. (Author/JN)

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PREDICTING ACHIEVEMENT IN COMMUNITY COLLEGE SCIENCE STUDENTS

by

Janet May Dettloff

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Education)
in The University of Michigan
1982

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ABSTRACT

PREDICTING ACHIEVEMENT IN COMMUNITY COLLEGE SCIENCE STUDENTS

by

Janet May Dettloff

Chairman: Burton E. Voss

This research study was designed to formulate a predictive equation which could be utilized to identify those students who most probably would not succeed in science education. Data were collected from 420 students enrolled in the General Biology Course at a largely urban mid-western community college which serves a heterogeneous population. The data included background characteristics, reading ability, math ability, and cognitive development level. The instruments used to collect these data were: (1) College Biology Student Survey, (2) The Nelson Denny Reading Test, Form F, (3) The CGP Applied Arithmetic Test, and (4) An Inventory of Piaget's Developmental Tasks.

The data showed that the General Biology classes had a higher percentage of females (82%) than males (18%). The students' median age was 26. The classes were racially balanced (49% white, 51% non-white). The majority of the students (71%) were single or formerly married. The

students' average math score was 15 correct answers out of 25 choices on a math test approximately sixth grade level. The students' average reading ability was the twelfth grade level. Only 9% of the students were at the formal level of cognitive development. The average grade was 2.7 (C+).

Multiple regression was used for the analyses. Background characteristics, reading and math ability accounted for 42% of the variance in the students' cognitive development and 43% of the variance in the students' achievement. Cognitive development accounted for 12.8% of the variance in the students' achievement. With cognitive development as a mediating variable, the background characteristics, reading and math ability accounted for 22% of the variance in the students' achievement. The predictive equation formulated was:

$$Y' = 0.42 + 0.14 \text{ cognitive development} + 0.18 \text{ reading ability} + 0.13 \text{ math ability} + 0.04 \text{ race} + 0.04 \text{ mothers' occupation} + 0.07 \text{ fathers' education} + -0.11 \text{ number of siblings} + -0.06 \text{ marital status.}$$

Recommendations were made about the improvement of these students in the basic skills area.

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To My Family

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Dr. Burton E. Voss, my advisor and the chairman of my committee, for his steadfastness, patience and encouragement in all phases of my graduate studies.

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TABLE OF CONTENTS

DEDICATION ii

ACKNOWLEDGMENTS iii

LIST OF TABLES viii

LIST OF FIGURES x

LIST OF APPENDICES xi

CHAPTER

I. INTRODUCTION 1

Background and Need for the Study 3
Purpose and Plan of the Study 6
Rationale for Selecting the Variables . . . 10
Research Hypotheses 11
Assumptions of This Study 13
Limitations of the Study 13
Significance of the Study 13
Summary 14

II. REVIEW OF THE RELATED LITERATURE 15

Introduction 15
The Relationship of Background Characteristics to Achievement in Community College Students 15
The Relationship of Background Characteristics to Achievement in Science Education 17
Piagetian Cognitive Development 18
Relationship of Background Characteristics to Cognitive Development 21
The Relationship Between Reading and Math Ability and Cognitive Development 23
The Relationship of Reading and Math Ability to Achievement in Community College Students 26

The Relationship of Reading and Math Ability to Achievement in Science Education 26
Relationship of Cognitive Development to Achievement in Science Education 27
Summary of the Research 29

III. RESEARCH PROCEDURES 30

Selection and Description of the Sample . . 30
Description of the Test Measures 31
Description of Achievement in Science Education 39
Data Collection 40

IV. ANALYSIS OF DATA 43

Description of the Variables 45
Analysis of the Data 61
Analyses of Background Characteristics . . 63
  Research Hypothesis One 63
  Research Hypothesis Two 79
Analyses of Reading and Math Ability . . . 85
  Research Hypothesis Three 85
  Research Hypothesis Four 88
Analysis of Cognitive Ability and Achievement in Science Education 90
  Research Hypothesis Five 90
Analysis in Background Characteristics, Cognitive Development and Achievement in Science Education 93
  Research Hypothesis Six 93
Analysis of Reading and Math Ability, Cognitive Development and Achievement in Science Education 93
  Research Hypothesis Seven 93
Analysis of All Variables and Achievement in Science Education 95
  Research Hypothesis Eight 95
Analysis of Cognitive Development as an Intervening Variable 96
  Research Hypothesis Nine 96
Summary 107

V. SUMMARY, CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS 109

Summary 109
Data Analysis 110
Conclusions 119
Discussion 122
Achievement 126
Recommendations 127

APPENDICES 130

REFERENCES 205

LIST OF TABLES

Table 1. Summary of the IPDT 34

Table 2. Problem Area Skills 35

Table 3. Summary of Demographic Data 46

Table 4. Summary of Reading and Math Ability . . . 51

Table 5. Summary of 18 IPDT Tasks 52

Table 6. Summary of Five IPDT Problem Area Skills 55

Table 7. Summary of Grades 60

Table 8. Summary Statistics of the Individual Background Characteristics as Related to Total Score on the IPDT 72

Table 9. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Relations . . 73

Table 10. Summary Statistics of the Individual Background Characteristics as Related to the Probelm Area Skill, Imagery . . . 74

Table 11. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Conservation 75

Table 12. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Classification 76

Table 13. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Proportional Reasoning 77

Table 14. Summary Statistics of the Combined Background Characteristics as Related to Total Score on the IPDT and the Five Problem Area Skills 80

Table 15. Summary Statistics of the Individual Background Characteristics as Related to Achievement in Science Education . . . 83

Table 16. Summary Statistics of the Combined Background Characteristics as Related to Achievement in Science Education . . . 84

Table 17. Summary Statistics of the Reading and Math Ability as Related to Total Score and the Five Problem Area Skills 89

Table 18. Summary Statistics of the Reading and Math Ability as Related to Achievement in Science Education 91

Table 19. Summary Statistics of Cognitive Development as Related to Achievement in Science Education 92

Table 20. Summary of the Multivariate Statistics of the Combined Background Characteristics, Reading and Math Ability and Cognitive Development as Related to Achievement in Science Education 94

Table 21. Path Analysis Residuals 100

Table 22. Partial Betas of Achievement in Science Eduction 104

Table 23. Correlation Matrix 106

LIST OF FIGURES

Figure 1. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability and Cognitive Development 8

Figure 2. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability Achievement in Science Education 8

Figure 3. Simple Paradigm Showing Relationships of Variables 9

Figure 4. Paradigm 98

Figure 5. Path Analysis Paradigm 102

LIST OF APPENDICES

Appendix A. Request for Permission for Research Study 131

Appendix B. Approval of Research Study 132

Appendix C. Random Selection Procedures 133

Appendix D. The College Biology Student Survey . . . 134

Appendix E. An Inventory of Piaget's Developmental Tasks 143

Appendix F. Student Consent Form 192

Appendix G. Report of Individual Scores 193

Appendix H. Table of Demographic Data 196

Appendix I. Summary of the 72 Item IPDT 201

CHAPTER I

INTRODUCTION

The community college is an institution whose goal is to facilitate the entry and education of persons who do not fit the traditional college model: students having prior marginal academic performances and students 22-60+, having academic ability but having delayed their entrance to higher education (Cohen, 1982). To accomplish this goal an open-door policy is advocated.

> "The Carnegie Commission supports open access to the 'open-door' college for all high school graduates and otherwise qualified individuals. The community colleges have a particular role to play in assuring equality of opportunity to all Americans (Carnegie Commission on Higher Education 1970:2)."

In addition, the community college accomplishes its goal of attracting non-traditional students by establishing schools that are readily accessible to the community.

> "More than any other single factor, access depends on proximity ... the advent of the community college as a neighborhood institution did more to open higher education to broader segments of the population than did its policy of accepting those students who had not done well in high school (Cohen, 1982:11)."

Cohen summarizes the goal of community colleges for the non-traditional students:

> "The community colleges reached out to attract those who were not being served by traditional higher education, who could not afford the tuition, who could not take the time to attend college on a full-time basis, whose ethnic background had constrained them from participating, who had inadequate preparation in the lower schools, whose educational progress had been interrupted by some temporary condition, who had become obsolete in their jobs or who had never been trained to work at any jobs, who needed a connection to obtain a job (Cohen, 1982:21)."

The concept of a two-year college which would replace the first two years of a college or university was proposed by Henry Tappan, President of The University of Michigan in 1851. This idea was periodically reiterated throughout the next century, but the concept was neither accepted nor implemented. The 1947 President's Commission on Higher Education promoted the idea that an additional two years of formal schooling beyond the high school could benefit at least half of the population.

The need for trained industrial workers, the drive for social equality and the need for continual custodial care of extended adolescents became the primary social forces which contributed to the dramatic expansion of community colleges from eight schools in 1900 to over twelve hundred in 1981 (Cohen, 1982). Career education and vocational/technical education as well as the first two years of a liberal arts education are now important facets of a community college.

Four million students enrolled in community colleges in 1980 in contrast to only one-half million in 1960. Students 25 or older have shown the highest increase (Chronicle of Higher Education, May, 1981). "The increase in enrollments was accompanied by a major change in the composition of the student body ... the (community) colleges were opened to ethnic minorities, to lower income groups and to those whose prior academic performance had been marginal (Cohen, 1981)."

Background and Need for the Study.

An example of such a community college is Wayne County Community College (WC_3) which serves as the setting for this research study.

WC_3 was founded in 1967 as mandated by the Michigan State Legislature. Located in Michigan's largest and most highly industrialized area, Wayne County, WC_3's occupational/vocational/career programs are a major commitment to its student population. In addition, WC_3 offers the traditional liberal arts college transfer programs. In 1976, WC_3 became a fully accredited member in the North Central Association of Colleges and Schools.

"WC_3 is designed to provide high quality, low cost education to all within the community who need and want it and to offer this opportunity with minimal restrictions (WC_3 Catalog)." WC_3 has an open-door admission policy.

This means that for any student interested in a general studies program admission is automatic if the student is 18 or older. There are no entrance requirements nor admission tests.

WC_3 is a large urban institution with five regional centers/campuses which serve the whole of Wayne County. Each of its five regional centers/campuses provides full liberal arts and career programs as well as supporting student services facilities. The students range from the white/non-white, affluent, middle class to the poor, white/non-white, inner-city lower class. WC_3 students are a diverse group of students: day and evening, younger and older, full and part-time, frequently employed, sometimes returning to college after a prolonged hiatus. All are seeking higher education for myriad reasons. The majority of the students at WC_3 are the non-traditional adult learners. With its open-door policy and its five regional campuses, WC_3 encourages these non-traditional students to return to school.

In the Fall Semester, 1981, 21,109 students were enrolled at WC_3 making WC_3 the largest community college in Michigan. Sixty-three percent of its students are women. Over 50% of its student population is black, 44% is white, the remainder are a mixture of other racial and ethnic backgrounds. Nearly half of the students are married.

WC_3's enrollment reflects the concept of the non-traditional student body reported by Cross and Cohen.

Because WC_3 has an open-door policy, instructors are concerned with the diverse background experiences and scholastic abilities of the students entering their courses The Biology instructors have been concerned with this problem, particularly in regard to the General Biology course. This is a one-semester course which students take for many reasons: as the basic, pre-requisite course for all advanced biology courses, as a requirement for a variety of programs and also as a degree requirement for those students seeking an Associate of Arts degree. Classes with this heterogeneous student population present problems for the instructors. The instructors strive to provide for the individual differences of students and, in particular, those students who have had a high failure rate. By identifying students prone to failure before they take the General Biology course, the self-fulfilling prophecy of failure can be circumvented. Thus, the identification of the students' background characteristics and their relationship to achievement in science education became the primary focus of this study. Findings of the study would be helpful to students and instructors in attempting to meet the individual needs of both.

Purpose and Plan of the Study.

The major purpose of the study was to collect data on background characteristics of students enrolled in General Biology at WC_3. These data were sex, age, race, marital status, parents' occupation, parents' education, number of siblings, math ability, reading ability, and cognitive development level. The data were then analyzed to determine how they affected achievement in science education.

More specifically the research design was developed to:

(1) Examine and analyze the students' background characteristics and their reading and math abilities as they relate to the students' cognitive development.

(2) Examine and analyze the students' background characteristics and their reading and math ability as they relate to the students' achievement in science education.

(3) Examine and analyze the students' cognitive development as it acts as a mediating variable between the students' background characteristics, and their reading and math ability with their achievement in science education.

(4) Establish a predictive equation to identify students who may not succeed in science education.

The research paradigm of the study is shown in Figures 1, 2 and 3. The general plan of the study was to collect the demographic data from the students by a questionnaire, the College Biology Student Survey, designed and administered by this researcher. Reading ability, scored as the grade level, was determined by the Nelson Denny Reading Test, Form F. Math ability, given in standard scores, was determined by the College General Placement Applied Arithmetic Test. Cognitive development was assessed by The Inventory of Piaget's Developmental Tasks (IPDT). It determines the students' level of cognitive development. The IPDT is pictorial and has a minimal reading level so reading ability does not become a factor in taking the test. The IPDT assesses five problem area skills, Relations, Imagery, Conservation, Classification and Proportional Reasoning. These skills are necessary for attaining the formal level of cognitive development. Achievement in the General Biology course was determined by the letter grade assigned to the students by the instructors.

Other demographic data of interest to this researcher were ascertained by the questionnaire. These variables were: working experience(s) past and present, number of hours worked per week, financial resources, family income, number of children, if any, number of credit hours, math

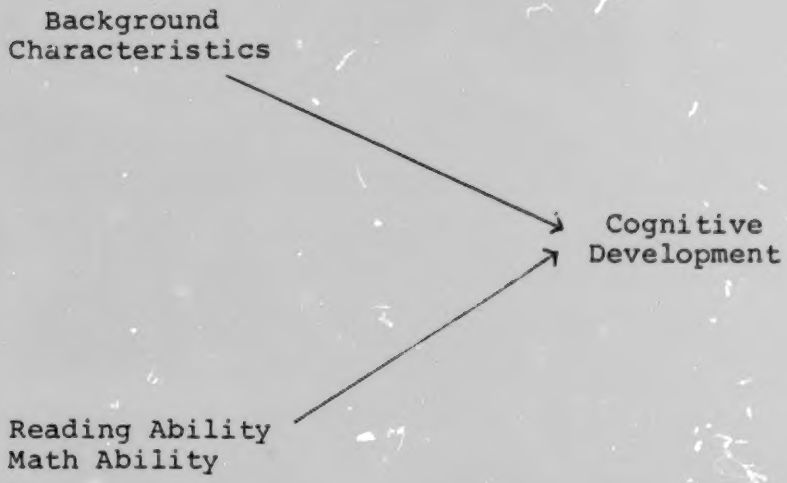

Background
Characteristics
Cognitive
Development
Reading Ability
Math Ability

Figure 1. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability and Cognitive Development.

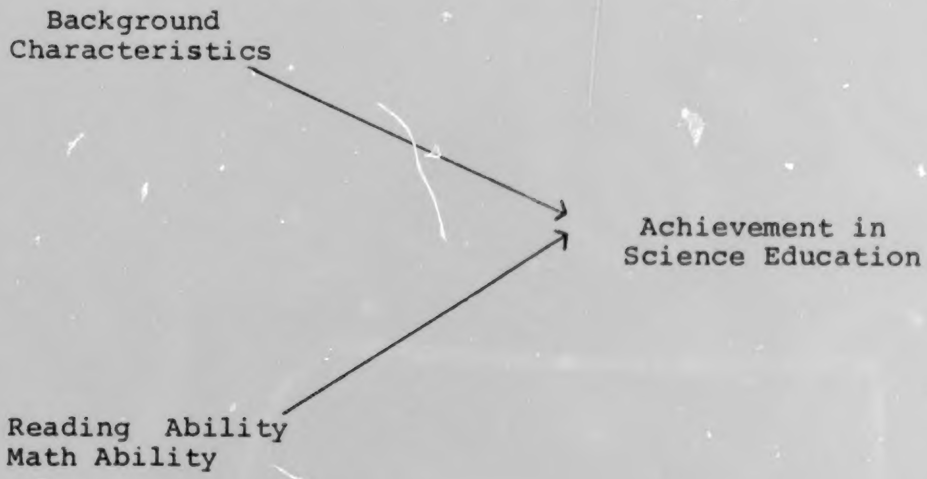

Background
Characteristics
Achievement in
Science Education
Reading Ability
Math Ability

Figure 2. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability Achievement in Science Education.

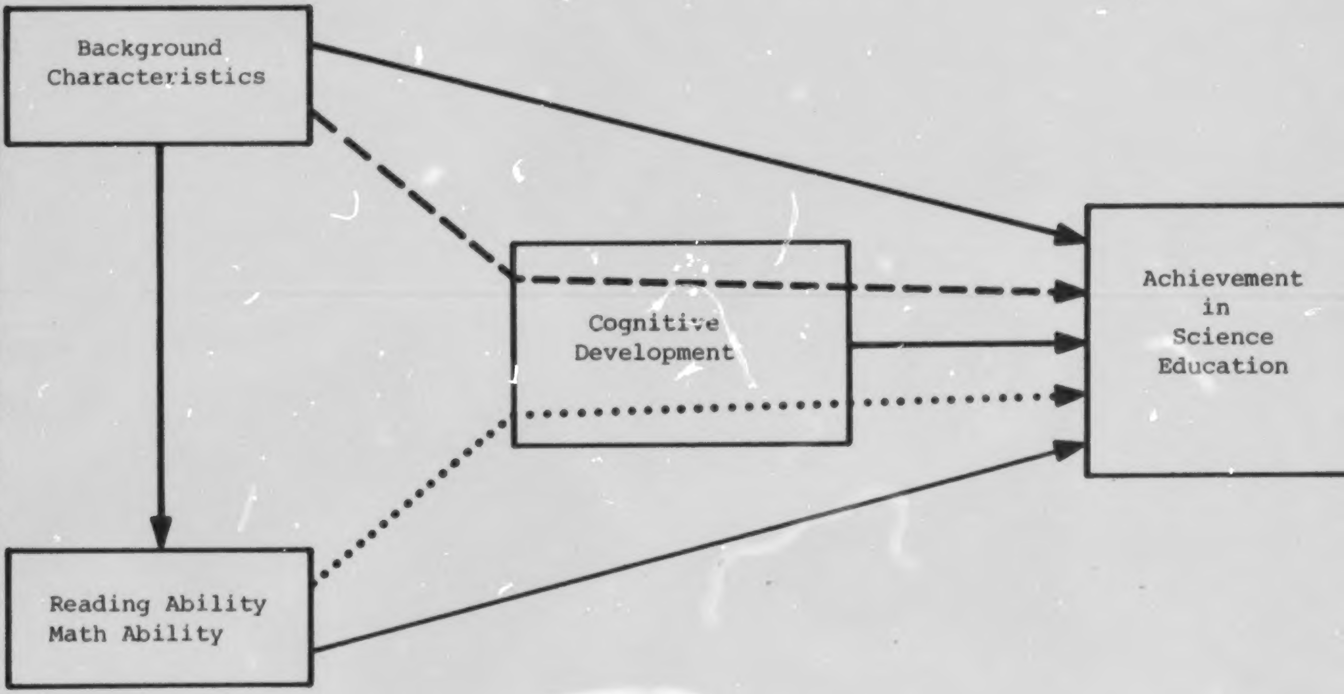

Background Characteristics
Cognitive Development
Achievement in Science Education
Reading Ability
Math Ability

Figure 3. Simple Paradigm Showing Relationships of Variables.

and science classes passed in high school and college, programs enrolled in, and reasons for attending WC_3.

Rationale for Selecting the Variables.

The needs and abilities of the students in the WC_3 General Biology course are varied and diverse. Students bring their life experiences to class with them. The literature noted differences in the life experiences of the adult learner at the community college from the life experiences of the traditional university student. Certain factors (variables) from these life experiences had an impact on cognitive development, grade and attrition. These variables are: sex, age, race, marital status, parents' education and occupation, reading ability and math ability or rather lack of math ability frequently expressed as a fear or dislike of math, inability to reason backwards (reversibility), to reason abstractly or to reason combinatorially.

Readings from the literature suggested that these variables did indeed play a role in cognitive development, attrition and achievement. However, the literature showed a dichotomy. Some readings showed a direct relationship between these variables and achievement and cognitive development; others did not show this relationship. The dichotomy from the literature piqued this researcher's curiosity and led in part to the research study.

Research Hypotheses.

The following research hypotheses were proposed:

Research Hypothesis One: A positive and direct relationship exists between the students' background characteristics and the cognitive skills the students have attained.

Research Hypothesis Two: A positive and direct relationship exists between the students' background characteristics and their achievement in science education.

Research Hypothesis Three: A positive and direct relationship exists between the students' reading and math ability and the cognitive skills the students have attained.

Research Hypothesis Four: A positive and direct relationship exists between the students' reading and math ability and their achievement in science education.

Research Hypothesis Five: A positive and direct relationship exists between the students' cognitive skills and their achievement in science education.

Research Hypothesis Six: A positive, direct linear relationship exists between the students' background characteristics, their cognitive skills and their achievement in science education.

Research Hypothesis Seven: A positive, direct linear relationship exists between the students' reading and math ability, their cognitive skills and their achievement in science education.

Research Hypothesis Eight: A positive, direct additive linear relationship exists between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

Research Hypothesis Nine: Cognitive development is an intervening variable between the independent variables, background characteristics, reading ability, math ability and the dependent variable, achievement in science education.

Research Hypothesis Nine A: There is a direct effect of cognitive development on achievement in science education independent of the overlapping effects of background characteristics, reading ability and math ability.

Research Hypothesis Nine B: There are direct effects of the background characteristics, reading ability and math ability on achievement in science education.

Research Hypothesis Nine C: There are indirect effects of background characteristics, reading ability and math ability on achievement in science education mediated by cognitive development.

Assumptions of This Study.

(1) Students would answer the questionnaire and the three test instruments to the best of their ability.

(2) Biology instructors would cover similar topics as predetermined by the course syllabus.

(3) The students' cognitive development could be measured by a paper and pencil test instrument.

(4) Achievement could be measured by the course grade.

Limitations of the Study.

(1) Even though the classes were randomly selected, students were self selected into their classes.

(2) Each biology instructor tests his/her own class and assigns the grade independently.

(3) Inferences cannot be made to the community college General Biology population.

(4) Inferences can be made to WC_3 General Biology students.

Significance of the Study.

Results from this research study could be utilized to develop a diagnostic test or tests to determine the students' academic strengths and weaknesses. A predictive equation could be formulated which counselors and General

Biology instructors at WC_3 could use to identify those students who most probably would not succeed in the General Biology course. These students could then be given tutoring, additional help and/or be placed in a remedial program.

Information from this research study can also be used as a rationale for developing a remedial biology course or for extending the current one semester course into a two semester course.

Summary.

WC_3 is a large urban community college with an open door policy which serves a heterogeneous student population. This study looks at the diversity of the General Biology students. The relationship of General Biology students' background characteristics, reading and math ability and cognitive development level to achievement in science education will be examined. The goal of this study is to identify high risk students by formulating a prediction equation using the above variables.

In Chapter II, the literature relating background characteristics, reading and math ability to the cognitive development level and to achievement in community colleges and, in particular, to science education at community colleges is presented.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Introduction.

Literature in educational research shows a continuing quest to determine factors which influence the students' scholastic achievement. Factors from DNA to environment have been explored for their relationship to achievement. Background characteristics, reading and math ability and cognitive development are factors which this researcher has deemed important and appropriate as determinants of the students' ability to achieve in science. Thus the review of the literature focused on the background variables and cognitive development as related to achievement in science education.

The Relationship of Background Characteristics to Achievement in Community College Students.

According to Bell (1966), Foxworth (1970), and Merritt (1972), the best predictors for success in a community college are sex, age, marital status and family income. Married students, male and female, performed better than their single counterparts but single females performed better than single males.

Reyes (1975) concluded that the student most likely to succeed at a community college will be a female, high school graduate, approximately 27 years old, in a liberal arts transfer program. Childs (1979) agreed that community college students 28 years or older were more likely to be high achievers than younger students.

According to Herridge (1971), the higher achievers in community colleges are older, predominantly white, married with children, work full-time and attend college part-time.

Ngo (1972) and Griffin (1978) found that females are more likely to have a higher GPA than males. They also conclude that older students and married students have a higher rate of achievement than younger students and single students.

However, Smoke (1955), Spector (1966) and Lindia (1971) found no relationship between sex, marital status and number of siblings on achievement.

Reyes (1975) and Griffin (1978) concurred with Spector (1966) that minority students as a group were not more likely to have a lower GPA than non-minority students.

Hay and Linsay's (1975) review of the literature on working college students concluded that part-time employment does not adversely affect achievement. In contrast, their study concluded that students who worked 16 hours or more per week had consistently lower GPA's than did the non-working students.

The fathers' level of formal education was a significant factor in predicting academic success according to Bossone (1965), Herridge (1971) and Fleming (1972). But Lindia (1971) found no significant relationship between father's educational level and student achievement.

The Relationship of Background Characteristics to Achievement in Science Education.

Jenkins (1966), Bennett (1970), Croft (1972) and Demas (1977) found no significant relationship between sex and achievement in freshman biology while Spurlin (1968) and Moss (1979) found that sex bias effects are present. Durst (1968) concluded that male students scored significantly higher than females in college biology.

Emmeluth (1979) found that males achieved better than females. He also found that older students achieved better than younger students in college biology. Demas (1977) concurred that there is a significant relationship between age and achievement.

Demas (1977) found that married students were more likely to achieve in college biology than single students.

McCall (1972) found that students who were employed part-time achieved significantly higher than those who worked full-time or those who did not work. In contrast, Williams (1972) found no correlation between working, full or part-time, and achievement in college biology.

The relationship of background characteristics to achievement in community college science education is not clear. A dichotomy is found in the literature on many factors. Further research is necessary to resolve these conflicts.

Piagetian Cognitive Development.

Piaget has defined four basic sequential stages of development starting from birth: the sensory motor from 0 - 2 years, the preoperational from 2 - 7 years, the concrete operational from 7 - 12 years or older, and the formal operational from 12 - 17 years or, more recently, 15 - 16 years to adult (Padilla, 1978). However, Piaget cautions that "there are no static stages as such. Each is the fulfillment of something begun in the preceding one and the beginning of something that will last on to the next (Dyli: 25)." Piaget also states that "the speed of development can vary from one individual to another and also from one social environment to another (Piaget, 1972:2)."

Since this research study is concerned with students 18 years or older, only the concrete and formal stages of cognitive development will be discussed.

According to Piaget, to reach a new level of cognitive development, one must successfully pass through each successive stage. Four factors influence the progression through these levels: maturation, physical experience, social experience, and equilibration.

In order to assimilate and accommodate the physical and social experiences into a mental construct or operation, a person must equilibrate. Sund (p. 13) states:

> "Equilibration is a mental, self-regulating process consisting of assimilation and accommodation. Assimilation involves absorbing information and incorporating it into mental schemes. Accommodation is the process of fabricating or modifying existing mental schemes. The schemes produced as a result of equilibration are general mental or organized patterns that the mind is capable of manifesting when the environment or will demands."

According to Piaget, a high school graduate should have reached the fourth stage of cognitive development, the formal operations stage. In order to accomplish this, he/she must have successfully passed through the third stage, concrete operations.

In the concrete operations stage, thought is restricted to what can be encountered in a direct experience. According to Padilla (1978), the mental operations developed in the concrete stage are:

(1) Logical problems can be understood and solved through manipulation of concrete objects or experience only.

(2) Actions and operations can be mentally reversed.

(3) Objects can be ordered and classified.

(4) Objects do not change in volume, weight or number when they are spatially rearranged (conservation).

Piaget states:

> "Concrete logical operations are actions performed on objects to bring them together into classes of various orders or to establish relations between them. One can also distinguish infralogical operations from concrete classifications or relational operations, their function is to integrate the parts of objects into a spatio-temporal whole (Piaget, 1958:273)."

In the formal-operational stage, thought is systematic and involves logically complex processes. It is abstract and manipulation of objects is no longer essential. According to Padilla, the mental operations developed in the formal stage are:

(1) Interaction in the hypothetical.

(2) Formulation and testing of hypotheses by identifying and controlling variables.

(3) Generation of multiple possibilities.

(4) Reflection on his/her own thought processes.

(5) Solving problems using proportional thought.

> "The principle novelty of this period (formal operations) is the capacity to reason in terms of verbally stated hypotheses and no longer merely in terms of concrete objects and their manipulation ... Hypothetical reasoning implies the subordination of the real to the realm of the possible, and consequently the linking of all possibilities to one another by necessary implications that encompass the real, but at the same time go beyond it (Piaget, 1972:4)."

According to Piaget (1972: 10), "all normal subjects attain the stage of formal operations or structuring if not between 11 - 12 to 14 - 15, in any case between 15 - 20 years. However, they reach the stage in different areas according to their aptitudes and their professional specializations."

Relationship of Background Characteristics to Cognitive Development.

According to Piaget, formal thinking should be achieved between 15 and 20 years of age. However, Lowell, Chiappetta, Renner, Cowan, Sund, Karplus, Lawson, Herron and others state that over 50% (50% - 85%) of American adults have not reached the formal level of development.

Miller's (1975) study demonstrated that at the formal level, differences could not simply be attributed to race or age. Experience, including cultural and socioeconomic influence, does affect cognitive processes. Karplus (1977) confirmed that there is a direct positive correlation between SES and the ability to perform proportional reasoning. Goolishian (1981) showed that their mothers' level of education was related to the students' cognitive development.

Karplus (1977) and Brendzel (1978) found that females were poorer than males in proportional reasoning. Delahanty (1977) and Kelly (1977) agreed that males were more advanced than females. Milakofsky (1982) found that on the IPDT males significantly outperformed females in conservation and proportional reasoning. Williams, et al. (1979) found that males scored higher than females on the Logical Reasoning Test. In contrast, Goolishian (1981) determined that females performed significantly better than males on the cognitive development test.

Tomlinson-Keasey (1972) and Coleman (1973) determined that cognitive ability declined with age (54 - 84). However, Hooper (1971) found that increments in intellectual abilities exist in some subjects until at least the mid-fifties.

Thus, numerous studies have concluded that sex and age play significant roles in attaining the formal level of development. Evidence also suggests that race, SES and life experiences affect cognitive development.

In Piaget's article on "Intellectual Evolution from Adolescence to Adulthood," he posits a rationale for the inability of some adults to achieve formal operations.

> "Briefly, our first interpretation would mean that in principle all normal individuals are capable of reaching the level of formal structures on the condition that the social environment and acquired experience provide the subject with the cognitive nourishment and intellectual stimulation necessary for such a construction.
>
> "However, a second interpretation is possible which would take into account the diversification of aptitudes with age ... We would go so far as to say that certain behavior

> patterns characteristically form stages with very general properties: this occurs until a certain level in development is reached; from this point onwards, however, individual aptitudes become more important than these general characteristics and create greater and greater differences between subjects ... In other words, our fourth period can no longer be characterized as a proper stage but would already seem to be a structural advancement in the direction of specialization (1972:8)."

Piaget concludes his article asking and then partially answering his own question.

> "The period from 15 to 20 years marks the beginning of professional specialization and consequently also the construction of a life program corresponding to the aptitudes of the individual. We now ask the following critical question: Can one demonstrate, at this level of development as at previous levels, cognitive structures common to all individuals which will, however, be applied or used differently by each person according to his particular activities?
>
> "The reply will probably be positive but this must be established by the experimental methods used in psychology and sociology. Beyond that, the next essential step is to analyze the probable processes of differentiation; that is to say, whether the same structures are sufficient for the organization of varying fields of activity but with differences in the way they are applied, or whether there will appear new and special structures that still remain to be discovered and studied (1972:15)."

The Relationship Between Reading and Math Ability and Cognitive Development.

Piaget's theory of cognitive development is based on logic and mathematics. He believes that certain logico-mathematical structures make very good models of the actual organization and process of cognition.

According to Flavell (1963):

> "Mathematics is involved in both the structure of the theory and in the content of the experimental work. The theory of intellectual development makes use of logico-algebraic systems-groups, lattices, and groupings -- in its treatment of intellectual structure. Similarly, the perception theory is definitely a quantitative affair involving equations with variables and constants which take their values from experimental data. It seems to be true that Piaget strives always to give mathematical-logical expression to theoretical constructs whenever the latter lend themselves to such treatment. Moreover, he tries to select the kind of expression most appropriate to the behavior formalized: qualitative and non-numerical algebra for conceptual structures; quantitative equations for certain aspects of perceptual functioning (p. 34)."

Wadsworth (1978) states that "Piaget has never done any research on reading and except for stressing movitation, has no opinion (p. 127)." However, Wadsworth emphasizes that Piaget's theory suggests several considerations for reading:

> "Within a Piagetian framework, one can conceptualize the child as approaching the task of learning how to read in the same manner in which the child intuitively approaches any situation. The child confronted with graphic symbols that do not make sense to him tries to assimilate and accommodate these symbols in an effort to make sense out of the written aspects of language. The child tries to 'break the code' that words and sentences present. The child tries to organize and integrate into his cognitive structures the reading process. As with other learnings, learning to read is a process of construction. The child internally gives

> increasingly more accurate structure to the written aspects of representation (p. 126)."

Several research studies have clearly shown the relationship between cognitive development and reading and math ability.

Raven, Hannah and Doran (1974) defined reading comprehension as the ability to associate concepts and to relate these concepts in various ways. The Iowa Silent Reading Test and Raven's Test of Logical Operations to measure cognitive ability was administered to 123 black college freshmen enrolled in an introductory physical science course. The reading test was significantly related to cognitive development and explained 25% of the variance of cognitive development.

McKinnon and Renner (1971) found a significant relationship between the level of cognitive development and the ACT verbal and math scores for the above average students but no significant relationship was found for below average students.

Milakofsky and Bender (1981) concluded that a relationship exists between the IPDT and SAT verbal and math scores from a research study of 225 introductory/remedial college chemistry students. The correlation between the IPDT and the SAT math score was much higher than the correlation with the IPDT and SAT verbal scores.

The Relationship of Reading and Math Ability to Achievement in Community College Students.

Most of the literature showed a direct positive correlation between reading and math ability generally measured by the SCAT, SAT and ACT and achievement in community college students.

Foxworth (1970), Curran (1971), Merritt (1972) and Nagle (1976) concluded that reading and math scores showed a significant relationship to achievement in community college students.

However, Reyes (1975) disagreed and showed that reading and math test scores were not able to predict achievement. Beach (1968) also concluded that the usual academic predictors of college success such as high school GPA, class rank and SAT scores, are of no use in predicting the first year cumulative GPA of marginal students.

The Relationship of Reading and Math Ability to Achievement in Science Education.

Spurlin (1968), Emmeluth (1979) and Geis (1979) determined that scores on the Nelson-Denny Reading Test were significantly related to achievement in introductory college biology courses.

Jenkins (1966) concluded that while the rank in the students' high school graduating class is the best predictor, reading ability is the second best predictor of academic success in introductory college biology.

Chesson (1974) reported that the CGP reading score and the CGP mathematics score can predict successful achievement in science education.

Demas (1977) showed a direct significant relationship between ACT English and math scores and achievement in college biology.

Milakofsky and Bender (1981) found little correlation between SAT verbal and math scores and achievement in students taking a remedial college chemistry course. However, in an introductory chemistry course, a significant correlation was found between SAT reading and math scores and achievement. The math scores correlated much higher with achievement than did the verbal scores.

Relationship of Cognitive Development to Achievement in Science Education.

The majority of American adults do not attain the formal level of cognitive development. Since most General Biology courses are taught abstractly at the formal level, then the students' level of cognitive development could affect their achievement in science education.

According to Padilla (1978), formal students achieve considerably higher than concrete students in science education.

Cantu and Herron (1978) agreed with Padilla that formal operational students will attain abstract concepts better than concrete operational students. Their study showed that formal operational students achieve better than concrete operational students in chemistry.

Chiappetta (1976) and Lawson (1974) showed that formal operational students achieved significantly higher scores in science as a result of concrete instruction than they did from formal instruction.

Bender and Milakolsky (1982) demonstrated that the "A" student had a higher level of measured cognitive ability than did the other students. They also showed a positive correlation between the IPDT and achievement in a college chemistry course.

However, Albanese, et al. (1976) concluded that performance on written Piagetian tasks was not highly correlated with achievement and could explain little of the variance in the grade for introductory college chemistry.

This researcher agrees with the following statement by Padilla (1978, p. 8):

> "If a great number of our students are not formal operational, even by grade 12, and if concrete operational students do not learn formal concepts, then this leaves us with two alternatives. We can either concentrate on concrete concepts at the expense of the more abstract ideas of science or we can attempt to develop new teaching procedures that use concrete examples, models and other materials as much as possible in the hopes that a more concrete approach will prove successful (Padilla, 1978, p. 8)."

Summary of the Research.

Most of the research studies relating cognitive development to achievement in science education involved students at the primary and secondary educational levels. Few studies assessing the cognitive development of the community college students have been conducted. Fewer studies relating cognitive development to achievement at the community college level have been researched. There exists a paucity of literature on these topics. One of the purposes of this research study is to assess the cognitive development of community college science students; another is to examine the relationship between cognitive development and achievement in science education. Hopefully this research study can contribute some information to "flesh out" the sparse information currently available.

The description of the students who voluntarily participated in the study, the test measures and the data collection method used in the study are presented in Chapter III.

CHAPTER III

RESEARCH PROCEDURES

This chapter describes the methods, procedures and instruments utilized in conducting this study.

Selection and Description of the Sample.

This study was conducted at WC_3 which has five geographic, autonomous regional centers/campuses. Permission to allow WC_3 General Biology students to participate voluntarily in this study was obtained from the Council of Regional Deans (see Appendices A and B).

Initially, four General Biology courses were randomly selected from each region using an appropriate statistical procedure (see Appendix C). Each instructor's permission was obtained to allow his/her class to participate in the study.

The students from each selected class were asked to participate voluntarily in the study. Of the 467 students who initially participated, 420 students completed all the instruments. The students ranged from the traditional aged college student, 17 - 22 (39%) to the non-traditional college student, 22 - 60+ (61%). The median age of the studentswas 26. Classes were comprised of 82% females and 18% males. The students were racially balanced: 49% were white, 51% were non-white. Seventy-one percent of the students were single, divorced, widowed or separated; 29% were married. Eighty-four percent had graduated from high school. Seventy-eight percent were taking nine or more credit hours during the Fall, 1981, semester. Fifty-two percent were employed and of those employed, 77% worked 20 hours or more per week.

Description of the Test Measures.

The College Biology Student Survey. This survey was designed by this researcher to measure the students' demographic data. It was pretested four times with appropriate modification after each pretest. These modifications were made after consulting with the students, other instructors who administered the survey, and Dr. Alfred, Dr. Davidson and the other members of my Dissertation Committee. The students determined that the final form of the questionnaire was non-threatening, non-embarrassing, readable, understandable and easy to follow. When the final form of the survey was pretested, all the students answered all the questions (see Appendix D).

An Inventory of Piaget's Developmental Tasks. An inventory of Piaget's Developmental Tasks (IPDT) was developed by Dr. Hans Furth and Dr. Burton Ross of the Center for Research in Thinking and Language in the Department of Psychology of the Catholic University of America. The IPDT was designed to be used with Navaho children and was later used with deaf children. The Tasks are pictorial and have a minimal reading level. Therefore, reading ability is not a factor in taking this test. The IPDT is untimed. Most students finished in 35 to 45 minutes though a small number required up to an hour to complete the IPDT. The IPDT is a 72-item multiple choice paper and pencil instrument (see Appendix E). Each item has one correct answer out of four possible choices. It is designed to inventory the student's cognitive development skills. These skills are divided into 18 Tasks or subtests with four items per Task. Each Task is preceded by an answered example question. "The first question in each Task was intentionally made very easy so that a practice function was served and a check was possible on whether an individual had understood the Task (Ross, 1968)." Subsequent Tasks are as difficult or more difficult than previous Tasks assessing the same skill. If a student answered three out of four items correctly, that student was assessed to have developed that cognitive skill or Task (personal communication with Dr. Ross, February, 1982).

According to Patterson and Milakofsky (1980), "the criterion of 75% or more correct responses on items in a subtest (i.e., at least three out of four items) is used to define mastery of a subtest concept."

According to Dr. Ross (1968), some of the Tasks were literal translations of traditional Piaget experimental tasks into a paper and pencil format such as conservation of weight and volume and perspective while others involved somewhat novel adaptations.

The eighteen Tasks or subtests of the IPDT, the problem area and concept assessed are summarized in Table 1.

"The Inventory is divided into five problem areas: classification, relations, images, laws and conservation (Ross, 1968)." Relations and Imagery are represented by three Tasks. Conservation, Classification and Proportional Reasoning are represented by four Tasks. The 18 Tasks which are divided into the five problem area skills are summarized in Table 2.

Reliability.

Patterson and Milakofsky determined the reliability of the IPDT using test-retest reliability based on the coefficient of stability. They correlated total IPDT group test scores for eight groups (N = 542: 250 third, sixth and ninth grades; 210 college freshmen and sophomores and 60 adults in college continuing education) on two

Table 1. Summary of the IPDT

Task Number	Task Name	Problem Area	Concept Assessed
1	Quantity	Conservation	Conservation of Quantity
2	Levels	Images	Maintaining a Liquid Horizontal to General Horizontal Plane
3	Sequence	Relations	Ordinal Seriation
4	Weight	Conservation	Conservation of Weight
5	Matrix	Classification	Double (Horizontal and Vertical) Classification
6	Symbols	Classification	Classification Additive
7	Perspective	Images	Perspective of Other Person
8	Movement	Images	Movement Progression
9	Volume	Conservation	Conservation of Volume
10	Seriation	Relations	Seriation of Height
11	Rotation	Laws	Prediction of Gear Movement in Opposite Directions
12	Angles	Laws	Reciprocal Implications
13	Shadows	Laws	Shadow Perspective
14	Classes	Classification	Color, Size and Shape Classification
15	Distance	Conservation	Conservation of Distance
16	Inclusion	Classification	Verbal Classification
17	Inference	Relations	Verbal Transitivity
18	Probability	Laws	Probability

Table 2. Problem Area Skills

Relations	Imagery	Conservation
Sequence	Levels	Quantity
Seriation	Perspective	Weight
Inference	Movement	Volume
		Distance

Classification	Proportional Reasoning
Matrix	Rotation
Symbols	Angles
Classes	Shadows
Inclusion	Probability

administrations of the group test one month apart. The r for the college groups was 0.95 and 0.67.

Split-half reliability using the Spearman-Brown Formula yielded a reliability coefficient of 0.77 in samples of college students.

According to Patterson and Milakofsky (1980) these reliability data correspond closely to reliability studies on other Piaget tests by Lawson (1977) and Sheehan (1970). Their general conclusions concerning reliability:

> "are that the IPDT scores are reasonably stable over a short period for a wide range of age groups and that scores are not seriously affected by situational testing variables. Furthermore, the inventory has considerable internal consistency and appears to be measuring a lasting trait rather than a specific temporary trait (p. 348)."

The Applied Arithmetic Test. The College General Placement Applied Arithmetic Test (CGP) is a standardized test developed by the College Entrance Examination Board. It is a 20-minute test which consists of 25 multiple choice questions. Each question has one correct answer out of four possible choices. The test is designed to assess the ability of the student to solve problems relating to percentages, proportions, ratios, rates, and averages. It also assesses the ability of the student to interpret data involving graphs and charts. According to the CGP manual (1979), "an acceptable score could indicate that a student is ready for a course whose only mathematics prerequisites are computational skills and problem solving ability (p. 6)."

The scoring was standardized with a norming group of 30,912 college freshmen. The average score was set at 50. About two-thirds had scores between 40 and 60.

Reliability.

The reliability of the test was determined by using the Kuder-Richardson Formula 20. Using this method, the reliability coefficient was 0.83.

Validity.

The content validity was determined by mathematics experts. They identified the skills necessary for success in mathematics courses as taught in postsecondary institutions with an open admissions policy.

The Nelson-Denny Reading Test Form F. The Nelson-Denny Reading Test, Form F, is a standardized test developed by the Houghton Mifflin Company. It is a timed test. The Vocabulary section requires 15 minutes and the Comprehension section requires 20 minutes. The total test time is 35 minutes.

The scoring was standardized with a norming population of over 6,000 students from two-year colleges, 5,000 students from four-year colleges and universities and

14,000 students from 80 high schools. The grade equivalent score on this test ranges from 3.6 and 16.9.

Reliability.

The reliability of the test was determined by the alternative form reliability method. Using this method, the reliability coefficient for the Vocabulary section was 0.92. The reliability coefficient for the Comprehension section was 0.77.

Validity.

Context Dependence (CD1) is the validity measure used in this test. This kind of validity is important in a test containing interpretative exercises such as reading comprehension items. According to the Examiner Manual (1981), the CD1 measures the degree to which correct item responses are under the influence of the context. The CD1 is expected to be positive and significant. The CD1 for the reading test was 0.44. "The Context Independence (CI1) measures the degree to which examinees can answer the item through previous knowledge or the application of logic that does not require the context ... Context independence is an undesirable item characteristic and the CI1 is ideally zero or negative (p. 17)." The CI1 of Form F was 0.03.

Description of Achievement in Science Education.

The Life and Physical Sciences Department has a syllabus and course outline for the General Biology course. These documents describe the topics which must be taught in the course. However, instructors have some academic freedom. They decide the method, time and testing of these prescribed topics.

The instructors also determine their grading policy within the guidelines established by WC_3 academic policy.

"The academic policy on grading is (Wayne County Community College Catalog, 1981-83:44):

1. Grades indicating course completion with credit and recorded on the official transcript:

   A Excellent

   B Above Average

   C Average

   I Incomplete

2. Grades indicating course completion with no credit and recorded in the computer transcript file and grade reports only:

   D Poor (Below Average)

   E Failure to complete course requirements satisfactorialy

   WP Indicates official withdrawal only

   WI Indicates official withdrawal by institution. Failure to attend any class during the first five weeks of the semester

3. Satisfactory completion of a course is a grade of "C" or above. Grades below "C" do not count toward degree requirements or transfer credit."

This researcher requested the grading policies of the instructors who allowed their classes to participate in the study. With few exceptions, the majority of the instructors' grading policies were based on averaging the test scores (four to six instructors made tests) and assigning a grade based on the averaged points. The point-grade system is: 90 - 100 = A; 80 - 89 = B; 65 - 79 = C; 60 - 64 = D; Below 60 = E. Two instructors graded on the normal bell shaped curve. One instructor had a written report included with the test scores.

Data Collection.

The students in each selected class were asked to voluntarily complete the following forms:

(1) College Biology Student Survey
(2) An Inventory of Piaget's Developmental Tasks (IPDT)
(3) The CGP Applied Arithmetic Placement Test (CGP)
(4) The Nelson-Denny Reading Test, Form F

These procedures were conducted in two one-hour segments during separate class periods to prevent student fatigue. The survey and the IPDT were administered during the first hour of one class period. The CGP and the Nelson-Denny Reading Test were administered during the second class period. Weekday classes meet for two hours twice a week. The three Saturday classes were the only exceptions. Since these classes meet for four hours each Saturday of the semester, the procedures were administered in two one-hour segments with a break between the segments.

The students were told explicitly that their participation was voluntary in whole or in part and that they might choose not to answer a particular question(s).

The students were assured that all the results would be confidential. To maintain this confidentiality, they were asked to use their social security number on all forms. Each student's social security number was given a code by this researcher so that individual results were unidentifiable.

All the students who participated in this study signed consent forms (see Appendix F).

In two of the five regions (the Downtown Region and the Greenfield Region), 50% to 70% of the students in two classes decided not to participate in the study. A minimum of 80 students from each region was necessary to conduct the statistical tests. Additional General Biology classes from these two regions were selected randomly following the method described in Appendix C. This ensured equal representation from all regions. A total of 22 General Biology classes participated in this study.

When this researcher invited the voluntary participation of the students in the first two classes scheduled for testing, several students declined to participate and informed the researcher that "there was nothing in it for them."

In order to encourage participation, this researcher informed the remaining classes that interested students could be informed of their individual test scores by giving their instructor an envelope with their social security number written on it. The instructor then forwarded these envelopes to this researcher. The tests were scored and the results of those students who gave envelopes were written on a form letter (see Appendix G), placed in the envelopes and the envelopes were returned to the instructors for distribution. Confidentiality was maintained, but more students were motivated to participate because there was something in it for them.

This chapter described the selection and characteristics of the students who participated in the study, the description of the test measures and the method used in the data collection.

Following the collection of the data, the data were collated and processed for statistical analyses. The analyses of the data are reported in Chapter IV.

CHAPTER IV

ANALYSIS OF DATA

This chapter contains the data and the statistical analyses of the study. Research hypotheses and the appropriate null hypotheses are presented and tested. The level of significance (α) acceptable for the statistical tests is 0.05. This means that the probability of making a Type I error (rejecting the null hypothesis when it is true) could occur five times in 100 tests (Johnson, 1977). The significance level was set at 0.05 to reduce the probability of making a Type II error. A Type II error occurs when the null hypothesis is accepted when it is false. The probability of making a Type I error can be decreased by changing the significance level to 0.01. However, this increases the probability of making a Type II error.

Type I errors are a function of sample size and are reduced by a large sample. The N for this study is 420. Type II errors can also be reduced by the power of the statistical tests. Linear regression is a powerful statistical test because it is used with interval data in the dependent and independent variables.

> "Interval-level techniques are much more powerful than ordinal-level and nominal-level techniques. They permit us not only to measure how strongly related a pair of variables are but also to make a statement describing the effect of one variable on the other (Weisberg, 1977:196)."

It is a powerful statistical test because it can resist violation of the assumptions that the predicted (Y) values are assumed to be normally distributed and to have equal variances at each predictor (X) point (Kerlinger, 1973).

Some of the independent variables in the background characteristics are nominal data. If the nominal datum is a dichotomous variable (a variable on a two-point scale such as male, female), that variable can be treated as interval data (Andrews, 1981, Davidson, personal communication, 1981). Then linear regression can be used.

If the nominal datum is not a dichotomous variable, it can be changed into a dichotomous variable by the use of a dummy variable.

> "A dummy variable is a vector in which members of a given category are assigned an arbitrary number, while all others - that is, subjects not belonging to the given category - are assigned another arbitrary number ... They (dummy variables) can be used, for example, in combination with continuous independent variables ... When dealing with a categorical independent variable, one can express it appropriately with dummy variables and do a regression analysis with the dummy variables as the independent variables (Kerlinger, 1973:105,107)."

By having the significance level at 0.05 but with a large sample and by using dummy variables for nominal data, linear regression, a powerful statistical test, can be used. This reduces the probability of Type I and Type II errors.

Description of the Variables.

From the four test measures, the students' background characteristics, reading and math ability, cognitive skills and grades were obtained. To clarify this information, the descriptive measures of the variables, Relative Frequency Tables, were formulated.

The demographic data used in the statistical analyses are summarized in Table 3. The variables not used in the statistical analyses are summarized in Appendix H. The proportion of males to females enrolled in General Biology approximately reflects the proportion of males to females in the college. The racial proportion also reflects the racial balance in the school, therefore the data were not weighted.

Grouped according to age, the majority of the students (61%) are the non-traditional students, 39% of the students are the traditional college students, 17-22. WC_3 enrollment agrees with the statements of Cohen, Cross and Chickering concerning the age of the community college student.

It is interesting to note the bimodal distribution in total family income. Twenty-four percent of the students report income sources between $10,000 and $15,000; 32% of the students have incomes over $20,000.

Table 3. Summary of Demographic Data (N=420).

Variable	Category	N	%
Sex	Male	76	18
	Female	343	82
		420	100
Age	17 - 22	163	39
	23 - 30	126	30
	31 - 40	85	20
	41 - 50	32	8
	Over 50	13	3
		419	100
Race	White	206	49
	Black	197	47
	Other	17	4
		420	100
Marital Status	Single, Separated, Divorced, Widowed	296	71
	Married, Living Together	121	29
		417	100

Table 3 (continued)

Variable	Category	N	%
Fathers' Occupation	Professional	42	10
	Manager	47	11
	Sales	15	4
	Clerical	10	2
	Service	33	8
	Crafts	67	16
	Factory Worker	79	19
	Laborer	43	10
		336 (420)	80 (100)
Mother Employed	Yes, Full Time	155	37
	Yes, Part Time	53	13
	No	177	42
		385 (420)	92 (100)

Table 3 (continued)

Variable	Category	N	%
Mothers' Occupation	Professional	29	7
	Manager	10	2
	Sales	19	5
	Clerical	38	9
	Service	70	17
	Crafts	4	1
	Factory Worker	32	8
		202 (420)	59 (100)
Fathers' Education	Don't Know	64	15
	Elementary School	71	17
	Some High School	69	16
	Finish High School	80	19
	Technical School	38	9
	Some College	45	11
	Associate Degree	13	3
	Bachelor Degree	26	6
	Graduate School	14	3
		420	100

Table 3 (continued)

Variable	Category	N	%
Mothers' Education	Don't Know	47	11
	Elementary School	53	13
	Some High School	93	22
	Finish High School	114	27
	Technical School	16	4
	Some College	52	12
	Associate Degree	18	4
	Bachelor Degree	13	3
	Graduate School	14	3
		420	100
Number of Siblings	0	66	16
	1	114	27
	2	92	22
	3	78	19
	>3	70	16
		420	100

Students reported they attend WC_3 for numerous reasons. Their primary reason for attending WC_3 is to achieve a personal goal, such as Allied Health Programs, followed closely by a desire to improve themselves. Less important is WC_3's closeness to home and the programs offered by the college.

The reading and math ability scores are summarized in Table 4. Surprisingly, the students have an average reading level of the twelfth grade. Many instructors assumed WC_3 students had a ninth or tenth grade reading level. The CGP mean, 15 questions answered correctly, showed a lack of math ability. The CGP is the most elementary math test (about sixth grade level) available from the College Board. Only 16% of the students could answer 20 or more problems correctly out of a total of 25 possible correct answers.

The results of the 72-item IPDT are summarized in Appendix I.

The 18 Tasks of the IPDT are summarized in Table 5. When the results of the IPDT Tasks were ranked by percentage of students not having the skill, Tasks 9, Conservation of Volume, 11, Rotation, 12, Angles, 14, Classes and 15, Conservation of Distance, are the most difficult. Fewer than half of the students have skills in these areas.

Table 4. Summary of Reading and Math Ability (N=420).

Ability	Category	N	%
Reading	Third - Sixth Grade	31	7
	Seventh - Ninth Grade	56	13
	Tenth - Twelfth Grade	119	29
	Thirteenth - Sixteenth Grade	166	40
	Seventeenth Grade	47	11
		419	100
$\overline{X} = 12$	S.D. = 3.48		
Math	1 - 5	13	3
(expressed in total number of correct answers on 25 question test)	6 - 10	80	19
	11 - 15	147	35
	16 - 20	112	27
	21 - 25	68	16
		420	100
$\overline{X} = 15$	S.D. = 5.06		

Table 5. Summary of 18 IPDT Tasks (N=420).

Task	Have Ability*		Do Not Have Ability	
	N	%	N	%
1. Conservation of Quantity	304	72	115	27
2. Levels - Images	368	88	52	12
3. Sequence - Relations	324	77	96	23
4. Conservation of Weight	365	87	55	13
5. Matrix - Classification	375	89	45	11
6. Symbols - Classification	349	83	71	17
7. Perspective - Images	249	59	171	41
8. Movement - Images	232	55	188	45
9. Conservation of Volume	165	39	255	61
10. Seriation - Relations	386	92	34	8
11. Rotation - Laws	123	29	297	71
12. Angles - Laws	203	48	217	52
13. Shadows - Laws	238	57	182	43
14. Classes - Classification	50	12	369	88
15. Conservation of Distance	172	41	247	59
16. Inclusion - Classification	271	65	148	35
17. Inference - Relations	301	72	118	28
18. Probability - Laws	214	51	205	49

*Correctly answered 3 out of 4 subsets of the Task.

The Milakofsky and Bender (1981) test results were similar. They administered the IPDT to first-year chemistry college students attending a mid-size eastern commuter university. Their students' results showed Tasks 9, 11, 13, 14, 15 and 18 as the most difficult.

More than 70% of the students demonstrated their skills on Tasks 1, Conservation of Quantity, 2, Levels, 3, Sequence, 4, Conservation of Weight, 5, Matrix, 6, Symbols, 10, Seriation, and 17, Inference.

The chemistry students of Milakofsky and Bender also found Tasks 2, 3, 4, 5, 10 and 17 the easiest.

These results on the students' cognitive development agree with the Piagetian literature on the skills acquired first and last in the cognitive structure. Indeed, with a mean score of 49 successfully completed items, it can be clearly seen that most of the students are not at the formal level of cognitive development.

Examining the four individual items of the subtest on Conservation of Volume, the two items (35 and 36) dealing with the concept of water displacement showed the poorest results. Respectively, 56% and 69% of the students could not recognize that the amount of water displacement is a function of density and not mass.

In the Task, Rotation, students had difficulty in determining the proper position of gears after rotating one or more interlocking gears (items 41 and 42).

Sixty-three percent and fifty-seven percent of the students lacked this cognitive skill.

In the Task, Angles (item 45), 67% of the students showed the poorest results in determining the angles of incidence when bouncing a ball against a wall.

The Classification Task was the most difficult of all the Tasks. On all four items (53 to 56), 53% to 71% of the students could not group the objects by shape, color and size in a hierarchially classification.

The results of Milakofsky and Bender similarily showed that over 50% of the students did not have this cognitive skill.

Eighty-five percent of the students missed one item (60) on the Distance Task. This item required the student to understand that in a figure with a constant parameter, when the shape changes, the area changes. Ninety-seven percent of Milakofsky and Bender's students also missed this item. Therefore, this researcher believes this item is inappropriate and should be changed or eliminated from future tests.

The five problem area skills of the IPDT are summarized in Table 6. Students were the most proficient in Relations (59%), then Imagery (37%), Conservation (18%), Proportional Reasoning (11%) and least proficient in Classification (9%). According to Milakofsky and Bender (1982:209), "In the relations and imagery areas students

Table 6. Summary of Five IPDT Problem Area Skills (N=420).

	N	%
Relations		
Levels	368	88
Perspective	249	59
Movement	232	55
N Correct On		
3 Tasks*	247	59
2 Tasks	112	27
1 Task	46	11
0 Tasks	15	4
	420	101

*59% of the Ss have this skill.

	N	%
Imagery		
Levels	368	88
Perspective	249	59
Movement	232	55
N Correct On		
3 Tasks*	154	37
2 Tasks	146	35
1 Task	95	23
0 Tasks	25	6
	420	100

*37% of the Ss have this skill.

Table 6 (continued)

	N	%
Conservation		
Quantity	304	72
Weight	365	87
Volume	165	39
Distance	172	42
N Correct On		
4 Tasks*	75	18
3 Tasks	114	27
2 Tasks	149	36
1 Task	66	16
0 Tasks	16	4
	420	101

*18% of the Ss have this skill.

Table 6 (continued)

	N	%
Classification		
Matrix	375	89
Symbols	349	83
Classes	50	12
Inclusion	271	65
N Correct On		
4 Tasks*	38	9
3 Tasks	199	47
2 Tasks	129	31
1 Task	38	9
0 Tasks	16	4
	420	100

*9% of the Ss have this skill.

Table 6 (continued)

	N	%
Proportional Reasoning		
Rotation	123	29
Angles	203	48
Shadows	238	57
Probability	214	51
N Correct On		
4 Tasks*	44	11
3 Tasks	99	24
2 Tasks	96	23
1 Task	113	27
0 Tasks	68	16
	420	101

*11% of the Ss have this skill.

demonstrated a high level of mastery; in proportional reasoning these college students had the most difficulty."

When the subtests which proved to be the most difficult for the students were removed from the calculations, the percentage of students having the skill was greatly increased. If the subtest on Volume is removed from the Conservation skill, 65% of the students demonstrate this cognitive ability. If the subtest, Classes, is removed from Classification, the percentage of students having this ability increases to 55%. If the subtest, Rotation, is removed from the Proportional Reasoning skill, 23% of the students demonstrate this skill.

The analyses on grades (see Table 7) were computed on earned and unearned E's grouped together. This distinction was made because sometimes students come to class for several weeks, fail to drop the class officially, and therefore must be given an E (unearned) as a grade. An E that is earned means the student attended classes, took and failed the tests thereby earning an E. The mean grade in the General Biology course is a C+. Sixty-seven percent of the students who participated in this study earned a B or better in General Biology. This high rate of success may be attributed to the voluntary participation of the students. Marginal or poor students may have self-selected themselves out of the study. Difficulty in obtaining student participation from two regional centers was noted in

Table 7. Summary of Grades (N=420).

Grades	(Honor Points)	N	%
A	(4.0)	137	33
B	(3.0)	142	34
C	(2.0)	64	15
D	(1.0)	23	6
E	(earned)	17	4
E	(unearned)	27	6
I		7	2
WP		2	--
WI		1	--
		420	100

$\overline{X} = 2.7$.

Chapter II. These two centers were the inner city centers where many of the students could be expected to have marginal academic skills. Students who were failing may have dropped out before their class was tested. The high percentage of good grades could be attributed to good teaching or the grades could have been inflated by some instructors since the course tests are not standardized.

Analysis of the Data.

In these bivariate analyses, cognitive skills are classified in two ways:

(1) The total number of correct answers on the Inventory of Piaget's Developmental Tasks (IPDT).

(2) The five problem area skills as explained in Table 2, Chapter III, page 35.

The bivariate statistical analyses were performed on the total number of correct answers on the IPDT and on each individual problem area skill.

Simple linear regressions were computed for bivariate analyses. Multiple linear regressions were computed for the multivariate analyses.

The effect that a change of the independent variables has on the dependent variable can be measured by regression analysis. The regression coefficient (b or beta) measures how much the dependent variable is expected to change on the average with a unit change in the independent variable

(Johnson, 1977; Weinberg, 1977). The intercept constant, a, measures the point of the line where the independent variable intercepts the dependent variable. The independent variable measures 0 at this point.

The equation for a single linear regression, $Y' = a + bX$, can be expanded for multivariate analysis to $Y' = a + b_1X_1 + b_2X_2 + \ldots b_kX_k$. "In all regression problems, simple and multiple, the principle of least squares is used. In any prediction of one variable from another, there are errors of prediction ... The principle of least squares tells us, in effect, to so analyze the data that the squared errors of prediction are minimized (Kerlinger, 1973:30)."

To summarize the accuracy of a prediction and to demonstrate explicitly the magnitude of the relationship, the R, coefficient of multiple correlation, is calculated. The square of the multiple correlation coefficient, R^2, indicates the proportion of the variance of the dependent variable that is explained by the linear prediction from the independent variable.

The F-ratio determines whether the regression of X's on Y's is significant.

Analyses of Background Characteristics.

The background characteristic variables on which the bivariate analyses were calculated are: age, sex, race, marital status, parents' education, parents' occupation and number of siblings.

The variables, sex, race, marital status, parents' occupation and education, are nominal variables. These variables were calculated as dummy variables when used in a linear regression.

Research Hypothesis One.

A positive, direct relationship exists between the students' background characteristics and the cognitive skills the students have attained.

Hypothesis 1.1a: There is no significant difference between the students' sex and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 11.055 ($\alpha = 0.00$). The proportion of explained variance was 2.4%.

Hypothesis 1.1b: There is no significant difference between the students' sex and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was accepted. The F-ratio was 0.985 ($\alpha = 0.32$).

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 12.159 ($\alpha = 0.00$). The proportion of explained variance was 2.6%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 6.083 ($\alpha = 0.01$). The proportion of explained variance was 1.2%.

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 1.460 ($\alpha = 0.23$).

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 23.188 ($\alpha = 0.00$). The proportion of the explained variance was 5.1%.

Hypothesis 1.2a: There is no significant difference between the students' age and their total score on the IPDT.

This hypothesis was accepted. The F-ratio was 3.0266 ($\alpha = 0.08$).

Hypothesis 1.2b: There is no significant difference between the students' age and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was accepted. The F-ratio was 0.965 ($\alpha = 0.33$).

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 4.47 ($\alpha = 0.03$). The proportion of explained variance was 0.8%.

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 0.817 ($\alpha = 0.37$).

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 0.208 ($\alpha = 0.65$).

The null hypothesis for the problem area skill, Proportional Reasoning, was accepted. The F-ratio was 0.816 ($\alpha = 0.37$).

Hypothesis 1.3a: There is no significant difference between the students' race and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 86.525 ($\alpha = 0.00$). The proportion of explained variance was 17%.

Hypothesis 1.3b: There is no significant difference between the students' race and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 24.740 ($\alpha = 0.00$). The proportion of explained variance was 5.5%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 55.192 ($\alpha = 0.00$). The proportion of explained variance was 11.6%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 47.052 ($\alpha = 0.00$). The proportion of explained variance was 10.5%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 12.991 (α = 0.00). The proportion of explained variance was 2.8%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 68.113 (α = 0.00). The proportion of explained variance was 14%.

Hypothesis 1.4a: There is no significant difference between the students' marital status and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 5.064 (α = 0.02). The proportion of explained variance was 1%.

Hypothesis 1.4b: There is no signficant difference between the students' marital status and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 4.568 (α = 0.03). The proportion of explained variance (adjusted) was 0.9%.

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 0.244 (α = 0.63).

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 9.814 (α = 0.00). The proportion of explained variance was 2.1%.

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 3.199 (α = 0.07).

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 6.797 (α = 0.01). The proportion of explained variance was 1.4%.

Hypothesis 1.5a: There is no significant difference between the occupation of the students' fathers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 6.149 (α = 0.000). The proportion of explained variance was 7.9%.

Hypothesis 1.5b: There is no significant difference between the occupation of the students' fathers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 2.097 (α = 0.04). The proportion of explained variance was 1.8%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 3.474 (α = 0.00). The proportion of explained variance was 4%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 4.392 (α = 0.00). The proportion of explained variance was 5.4%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 3.474 (α = 0.00). The proportion of explained variance was 4%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 2.211 ($\alpha = 0.03$). The proportion of explained variance was 2%.

Hypothesis 1.6a: There is no significant difference between the occupation of the students' mothers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 2.748 ($\alpha = 0.01$). The proportion of explained variance was 2.8%.

Hypothesis 1.6b: There is no significant difference between the occupation of the students' mothers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 2.097 ($\alpha = 0.04$). The proportion of explained variance was 1.8%.

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 1.693 ($\alpha = 0.11$).

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 1.658 ($\alpha = 0.12$).

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 3.826 ($\alpha = 0.00$). The proportion of explained variance was 4.5%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 2.672 ($\alpha = 0.01$). The proportion of explained variance was 2.7%.

Hypothesis 1.7a: There is no significant difference between the level of education of the students' fathers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 4.962 ($\alpha = 0.00$). The proportion of explained variance was 6.2%.

Hypothesis 1.7b: There is no significant difference between the level of education of the students' fathers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 3.55 ($\alpha = 0.00$). The proportion of explained variance was 4.1%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 3.34 ($\alpha = 0.00$). The proportion of explained variance was 3.8%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 2.542 ($\alpha = 0.01$). The proportion of explained variance was 2.5%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 3.230 ($\alpha = 0.00$). The proportion of explained variance was 3.6%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 3.285 ($\alpha = 0.00$). The proportion of explained variance was 3.7%.

Hypothesis 1.8a: There is no significant difference between the level of education of the students' mothers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 4.187 ($\alpha = 0.00$). The proportion of explained variance was 5.1%.

Hypothesis 1.8b: There is no significant difference between the level of education of the students' mothers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 3.891 ($\alpha = 0.01$). The proportion of explained variance was 3.1%.

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 1.699 ($\alpha = 0.11$).

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 0.935 ($\alpha = 0.48$).

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 1.966 ($\alpha = 0.06$).

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 2.211 ($\alpha = 0.03$). The proportion of explained variance was 2%.

Hypothesis 1.9a: There is no significant difference between the students' number of siblings and their total score on the IPDT.

This hypothesis was accepted. The F-ratio was 0.334 ($\alpha = 0.57$).

Hypothesis 1.9b: There is no significant difference between the students' number of siblings and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was accepted. The F-ratio was 0.126 ($\alpha = 0.72$).

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 1.836 ($\alpha = 0.17$).

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 0.730 ($\alpha = 0.40$).

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 0.298 ($\alpha = 0.59$).

The null hypothesis for the problem area skill, Proportional Reasoning, was accepted. The F-ratio was 0.293 ($\alpha = 0.60$).

A summary of the statistics of the individual background characteristics related to total score is presented in Table 8. A summary of the statistics of the individual background characteristics related to the five problem area skills is presented in Tables 9 through 13.

After determining those background characteristic variables which are significant, a regression was

Table 8. Summary Statistics of the Individual Background Characteristics as Related to Total Score on the IPDT.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	11.055 (0.00)[b]	0.07	0.16	0.024 (2.4%)
Age	3.224 (0.07)	0.008	0.09	--
Race	86.523 (0.00)	0.17	0.42	0.172 (17.2%)
Marital Status	5.064 (0.02)	0.012	0.11	0.01 (1%)
Fathers' Occupation	6.149 (0.00)	0.10	0.31	0.079 (7.9%)
Mothers' Occupation	2.748 (0.01)	0.05	0.21	0.028 (2.8%)
Fathers' Education	4.962 (0.00)	0.08	0.28	0.062 (6.2%)
Mothers' Education	4.187 (0.00)	0.07	0.26	0.051 (5.1%)
Number of Siblings	0.334 (0.57)	0.001	0.0285	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 9. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Relations.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	0.985 (0.32)[b]	-0.05	0.05	--
Age	0.965 (0.33)	0.05	0.05	--
Race	24.74 (0.00)	-0.24	0.24	0.055 (5.5%)
Marital Status	4.568 (0.03)	0.10	0.10	0.01 (1%)
Fathers' Occupation	3.453 (0.00)	0.06	0.24	0.039 (3.9%)
Mothers' Occupation	2.097 (0.04)	0.03	0.19	0.018 (1.8%)
Fathers' Education	2.891 (0.01)	0.06	0.24	0.041 (4.1%)
Mothers' Education	3.555 (0.00)	0.05	0.22	0.031 (3.1%)
Number of Siblings	0.126 (0.72)	-0.02	0.02	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 10. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Imagery.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	12.159 (0.00)[b]	-0.17	0.17	0.026 (2.6%)
Age	4.470 (0.03)	0.10	0.10	0.09 (0.9%)
Race	55.192 (0.00)	-0.34	0.34	0.116 (11.6%)
Marital Status	0.244 (0.63)	0.02	0.02	--
Fathers' Occupation	3.474 (0.00)	0.06	0.24	0.04 (4%)
Mothers' Occupation	1.693 (0.11)	0.03	0.17	0.01 (1%)
Fathers' Education	3.340 (0.00)	0.05	0.23	0.038 (3.8%)
Mothers' Education	1.699 (0.11)	0.03	0.17	0.012 (1.2%)
Number of Siblings	1.836 (0.17)	0.07	0.07	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 11. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Conservation.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	6.080 (0.01)[b]	-0.12	0.12	0.012 (1.2%)
Age	0.817 (0.37)	-0.04	0.04	--
Race	47.052 (0.00)	-0.32	0.32	0.10 (10%)
Marital Status	9.814 (0.00)	0.15	0.15	0.021 (2.1%)
Fathers' Occupation	4.392 (0.00)	0.07	0.26	0.05 (5%)
Mothers' Occupation	1.658 (0.12)	0.03	0.17	0.01 (1%)
Fathers' Education	2.542 (0.01)	0.04	0.20	0.025 (2.5%)
Mothers' Education	0.935 (0.48)	0.02	0.13	--
Number of Siblings	0.730 (0.40)	0.04	0.04	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 12. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Classification.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	1.450 (0.23)[b]	-0.06	0.06	--
Age	0.208 (0.65)	0.02	0.02	--
Race	12.991 (0.00)	-0.17	0.17	0.028 (2.8%)
Marital Status	3.199 (0.07)	0.09	0.09	--
Fathers' Occupation	3.474 (0.00)	0.06	0.24	0.04 (4%)
Mothers' Occupation	3.826 (0.00)	0.06	0.25	0.045 (4.5%)
Fathers' Education	3.230 (0.00)	0.05	0.23	0.036 (3.6%)
Mothers' Education	1.966 (0.06)	0.03	0.18	0.016 (1.6%)
Number of Siblings	0.298 (0.59)	-0.03	0.03	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 13. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Proportional Reasoning.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	23.188 (0.00)[b]	-0.23	0.23	0.05 (5%)
Age	0.816 (0.37)	0.04	0.04	--
Race	68.113 (0.00)	-0.38	0.38	0.14 (14%)
Marital Status	6.797 (0.01)	0.13	0.13	0.138 (13.8%)
Fathers' Occupation	4.818 (0.00)	0.08	0.28	0.06 (6%)
Mothers' Occupation	2.672 (0.01)	0.04	0.21	0.027 (2.7%)
Fathers' Education	3.285 (0.00)	0.05	0.23	0.037 (3.7%)
Mothers' Education	2.211 (0.03)	0.04	0.04	0.02 (2%)
Number of Siblings	0.293 (0.60)	0.03	0.19	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

calculated to analyze their effect on the total IPDT score and each problem area skill.

Hypothesis 1.10a: There is no significant difference between the students' background characteristics and their total score on the IPDT.

This hypothesis was rejected. The F-ratio is 5.055 ($\alpha = 0.00$). The proportion of explained variance was 26%.

Hypothesis 1.10b: There is no significant difference between the students' background characteristics and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 2.115 ($\alpha = 0.00$). The proportion of explained variance was 7.4%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 6.011 ($\alpha = 0.00$). The proportion of explained variance was 16.1%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 5.774 ($\alpha = 0.00$). The proportion of explained variance was 15.5%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 2.848 ($\alpha = 0.00$). The proportion of explained variance was 8.9%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 4.923 ($\alpha = 0.00$). The proportion of explained variance was 22.5%.

A summary of the statistics of the combined background characteristics related to the total score is presented in Table 14. A summary of the statistics of the combined background characteristics related to the five problem area skills is presented in Table 14.

Research Hypothesis Two.

A positive, direct relationship exists between the students' background characteristics and their achievement in science education.

Hypothesis 2.1: There is no significant relationship between the students' sex and their achievement in science education.

This hypothesis was accepted. The F-ratio for the regression was 0.206 ($\alpha = 0.65$).

Hypothesis 2.2: There is no significant difference between the students' age and their achievement in science education.

This hypothesis was accepted. The F-ratio for the regression was 1.218 ($\alpha = 0.2$).

Hypothesis 2.3: There is no significant difference between the students' race and their achievement in science education.

Table 14. Summary Statistics of the Combined Background Characteristics as Related to Total Score on the IPDT and the Five Problem Area Skills.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Total Score on the IPDT	5.055 (0.00)[b]	0.32	0.56	0.256 (25.6%)
Relations	2.115 (0.00)	0.14	0.37	0.074 (7.4%)
Imagery	6.011 (0.00)	0.19	0.44	0.16 (16%)
Conservation	5.774 (0.00)	0.19	0.43	0.15 (15%)
Classification	2.848 (0.00)	0.14	0.37	0.09 (9%)
Proportional Reasoning	4.923 (0.00)	0.28	0.53	0.225 (22.5%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

This hypothesis was rejected. The F-ratio for the regression was 33.149 ($\alpha = 0.00$). The proportion of explained variance was 7%.

Hypothesis 2.4: There is no significance between the students' marital status and their achievement in science education.

This hypothesis was rejected. The F-ratio for the regression was 7.771 ($\alpha = 0.01$). The proportion of explained variance was 1.6%.

Hypothesis 2.5: There is no significant difference between the occupation of the students' fathers and the students' achievement in science education.

This hypothesis was accepted. The F-ratio was 1.271 ($\alpha = 0.26$).

Hypothesis 2.6: There is no significant difference between the occupation of the students' mothers and the students' achievement in science education.

This hypothesis was rejected. The F-ratio was 2.632 ($\alpha = 0.01$). The proportion of explained variance was 2.7%.

Hypothesis 2.7: There is no significant difference between the level of education of the students' fathers and the students' achievement in science education.

This hypothesis was rejected. The F-ratio was 2.154 ($\alpha = 0.04$). The proportion of explained variance was 1.9%.

Hypothesis 2.8: There is no significant difference between the level of education of the students' mothers and the students' achievement in science education.

This hypothesis was accepted. The F-ratio was 1.706 ($\alpha = 0.11$).

Hypothesis 2.9: There is no significant difference between the students' number of siblings and their achievement in science education.

This hypothesis was rejected. The F-ratio was 7.287 ($\alpha = 0.01$). The proportion of explained variance was 1.5%.

A summary of the statistics of the individual background characteristics related to achievement in science education is presented in Table 15.

After determining those background characteristic variables which are significant, a regression was calculated to analyze their effect on achievement in science education.

Hypothesis 2.10: There is no significant difference between the students' background characteristics and their achievement in science education.

This hypothesis was rejected. The F-ratio was 3.613 ($\alpha = 0.00$). The proportion of explained variance was 9.6%.

A summary of the statistics of the combined background characteristics related to achievement in science education is presented in Table 16.

Table 15. Summary Statistics of the Individual Background Characteristics as Related to Achievement in Science Education.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	0.206 (0.65)[b]	-0.02	0.02	--
Age	1.218 (0.2)	0.05	0.05	--
Race	33.149 (0.00)	0.27	0.27	0.07 (7%)
Marital Status	7.771 (0.01)	-0.14	0.14	0.02 (2%)
Fathers' Occupation	1.271 (0.26)	0.02	0.15	--
Mothers' Occupation	2.632 (0.01)	0.04	0.21	0.027 (2.7%)
Fathers' Education	2.154 (0.04)	0.04	0.19	0.02 (2%)
Mothers' Education	1.706 (0.11)	0.03	0.17	0.01 (1%)
Number of Siblings	7.287 (0.01)	-0.13	0.13	0.015 (1.5%)

[a] R^2 is the proportion of variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 16. Summary Statistics of the Combined Background Characteristics as Related to Achievement in Science Education.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Achievement in Science Education	3.613 (0.00)[b]	0.13	0.36	0.096 (9.6%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Analyses of Reading and Math Ability.

Research Hypothesis Three.

A positive and direct relationship exists between the students' reading and math ability and the cognitive skills the students have attained.

Hypothesis 3.1a: There is no significant difference between the students' reading ability and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 204.62 ($\alpha = 0.00$). The proportion of explained variance was 33%.

Hypothesis 3.1b: There is no significant difference between the students' reading ability and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 63.831 ($\alpha = 0.00$). The proportion of explained variance was 13.2%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 93.258 ($\alpha = 0.00$). The proportion of explained variance was 18%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 102.849 ($\alpha = 0.00$). The proportion of explained variance was 19.6%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 121.033 (α = 0.00). The proportion of explained variance was 22%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 67.44 (α = 0.00). The proportion of explained variance was 13.9%.

Hypothesis 3.2a: There is no significant difference between the students' math ability and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 212.35 (α = 0.00). The proportion of explained variance was 33.7%.

Hypothesis 3.2b: There is no significant difference between the students' math ability and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 55.11 (α = 0.00). The proportion of explained variance was 11.4%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 117.935 (α = 0.00). The proportion of explained variance was 21.8%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 69.603 (α = 0.00). The proportion of explained variance was 14%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 47.572 (α = 0.00). The proportion of variance explained was 10%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 114.479 (α = 0.00). The proportion of explained variance was 21.3%.

Hypothesis 3.3a: There is no significant difference between the linear additive effects of the students' reading and math ability and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 141.782 (α = 0.00). The proportion of explained variance was 40%.

Hypothesis 3.3b: There is no significant difference between the linear additive effect of the students' reading and math ability and their ability in each of the five problem skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 38.465 (α = 0.00). The proportion of explained variance was 15.2%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 68.439 (α = 0.00). The proportion of explained variance was 24.4%.

The null hypothesis for the problem skill, Conservation, was rejected. The F-ratio was 46.720 (α = 0.00). The proportion of explained variance was 18%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 29.715 (α = 0.00). The proportion of explained variance was 12%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 61.330 (α = 0.00). The proportion of explained variance was 22.4%.

A summary of the statistics of reading and math ability related to total score on the IPDT and the five problem area skills is presented in Table 17.

Research Hypothesis Four.

A positive and direct relationship exists between the students' reading and math ability and their achievement in science education.

Hypothesis 4.1: There is no significant difference between the students' reading ability and their achievement in science education.

This hypothesis was rejected. The F-ratio was 74.104 (α = 0.00). The proportion of explained variance was 15%.

Hypothesis 4.2: There is no significant difference between the students' math ability and their achievement in science education.

This hypothesis was rejected. The F-ratio was 61.995 (α = 0.00). The proportion of explained variance was 12.7%.

Table 17. Summary Statistics of the Reading and Math Ability as Related to Total Score and the Five Problem Area Skills.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Total Score on the IPDT	141.782 (0.00)[b]	0.41	0.63	0.40 (40%)
Relations	38.465 (0.00)	0.16	0.40	0.15 (15%)
Imagery	68.439 (0.00)	0.25	0.50	0.244 (24.4%)
Conservation	46.720 (0.00)	0.18	0.43	0.18 (18%)
Classification	29.715 (0.00)	0.13	0.35	0.12 (12%)
Proportional Reasoning	61.330 (0.00)	0.23	0.48	0.22 (22%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Hypothesis 4.3: There is no significant difference between the linear additive effects of the students' reading and math ability and their achievement in science education.

This hypothesis was rejected. The F-ratio was 43.809 ($\alpha = 0.00$). The proportion of explained variance was 17%.

A summary of the statistics of reading and math ability related to achievement in science education is presented in Table 18.

Analysis of Cognitive Ability and Achievement in Science Education.

Research Hypothesis Five.

A positive and direct relationship exists between the students' cognitive abilities and their achievement in science education.

Hypothesis 5: There is no significant difference between the students' total score on the IPDT and their achievement in science education.

This hypothesis was rejected. The F-ratio was 62.714 ($\alpha = 0.00$). The proportion of explained variance was 12.8%.

A summary of the statistics of cognitive development as related to achievement in science education is presented in Table 19.

Table 18. Summary Statistics of the Reading and Math Ability as Related to Achievement in Science Education.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Achievement in Science Education	13.809 (0.00)[b]	0.17	0.42	0.17 (17%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 19. Summary Statistics of Cognitive Development as Related to Achievement in Science Education.

	Cognitive Development			
	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Achievement in Science Education	62.714 (0.00)[b]	0.35	0.36	0.128 (12.8%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Analysis in Background Characteristics, Cognitive Development and Achievement in Science Education.

Research Hypothesis Six.

A positive and direct relationship exists between the students' background characteristics, their cognitive development and their achievement in science education.

Hypothesis 6: There is no significant difference between the linear, additive effects of the students' background characteristics, their cognitive development and their achievement in science education.

This hypothesis was rejected. The F-ratio was 5.792 ($\alpha = 0.00$). The proportion of explained variance was 17%.

A summary of the statistics of the combined effects of background characteristics and cognitive development as related to achievement in science education is presented in Table 20.

Analysis of Reading and Math Ability, Cognitive Development and Achievement in Science Education.

Research Hypothesis Seven.

A positive and direct relationship exists between the students' reading and math ability, their cognitive development and their achievement in science education.

Table 20. Summary of the Multivariate Statistics of the Combined Background Characteristics, Reading and Math Ability and Cognitive Development as Related to Achievement in Science Education.

Variable	Achievement in Science Education			
	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Combined Background Characteristics and Cognitive Development	5.792 (0.00)[b]	0.21	0.45	0.17 (17%)
Reading, Math Ability and Cognitive Development	32.762 (0.00)	0.19	0.44	0.186 (18.6%)
Combined Background Characteristics, Reading and Math Ability and Cognitive Development	6.753 (0.00)	0.25	0.50	0.22 (22%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Hypothesis 7: There is no significant difference between the linear, additive effects of the students' reading and math ability, their cognitive development and their achievement in science education.

This hypothesis was rejected. The F-ratio was 32.762 ($\alpha = 0.00$). The proportion of explained variance was 18.6%.

A summary of the statistics of the combined effects of reading and math ability and cognitive development as related to achievement in science education is presented in Table 20.

Analysis of All Variables and Achievement in Science Education.

Research Hypothesis Eight.

A positive, direct additive linear relationship exists between the students' background characteristics, reading and math abilities, total score on the IPDT and their achievement in science education.

Hypothesis 8: There is no significant difference between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

This hypothesis was rejected. The F-ratio was 6.753 ($\alpha = 0.00$). The proportion of explained variance was 22%.

A summary of the statistics of the combined effects of background characteristics, reading and math ability and cognitive development as related to achievement in science education is presented in Table 20.

Analysis of Cognitive Development as an Intervening Variable.

Research Hypothesis Nine.

Cognitive development is a mediating variable between the independent variables, background characteristics, reading ability, math ability and the dependent variable, achievement in science education.

Hypothesis 9a: There is a direct effect of cognitive development on achievement in science education independent of the overlapping effects of background characteristics, reading ability and math ability.

Hypothesis 9b: There are direct effects on the background characteristics, reading ability and math ability on achievement in science education.

Hypothesis 9c: There are indirect effects of background characteristics, reading ability, and math ability on achievement in science education mediated by cognitive development.

In order to determine the direct effect of cognitive development independent of the indirect effects of background characteristics, reading ability and math ability and the total indirect effects of background characteristics, reading ability and math ability, a different statistical technique, path analysis, was used.

> "Path analysis is not a method of discovering causes, but a method applied to a causal model formulated by the researcher on the basis of knowledge and theoretical considerations (Kerlinger, 1973:305)."

> "Path analysis techniques attempt to estimate the magnitude of causal 'pathways.' The causal sequence whose paths are to be estimated is specified by theoretical or hypothesis-testing considerations. Estimates of paths are arrived at by series of ordinary least square regressions, each dependent variable being regressed upon all other variables presumed to cause it (Futterman, 1980:33)."

According to Kerlinger (1973:310), "A path coefficient indicates the direct effect of a variable taken as a cause of a variable taken as an effect." The symbol for a path coefficient is a p with two subscripts. The first subscript indicates the dependent variable. The second subscript indicates the independent variable (see Figure 5).

A variable whose causes are determined by factors not under consideration in the model is an exogenous variable. No explanation of the variability of exogenous variables is given in the model. In Figure 4, Background Characteristics is an exogenous variable.

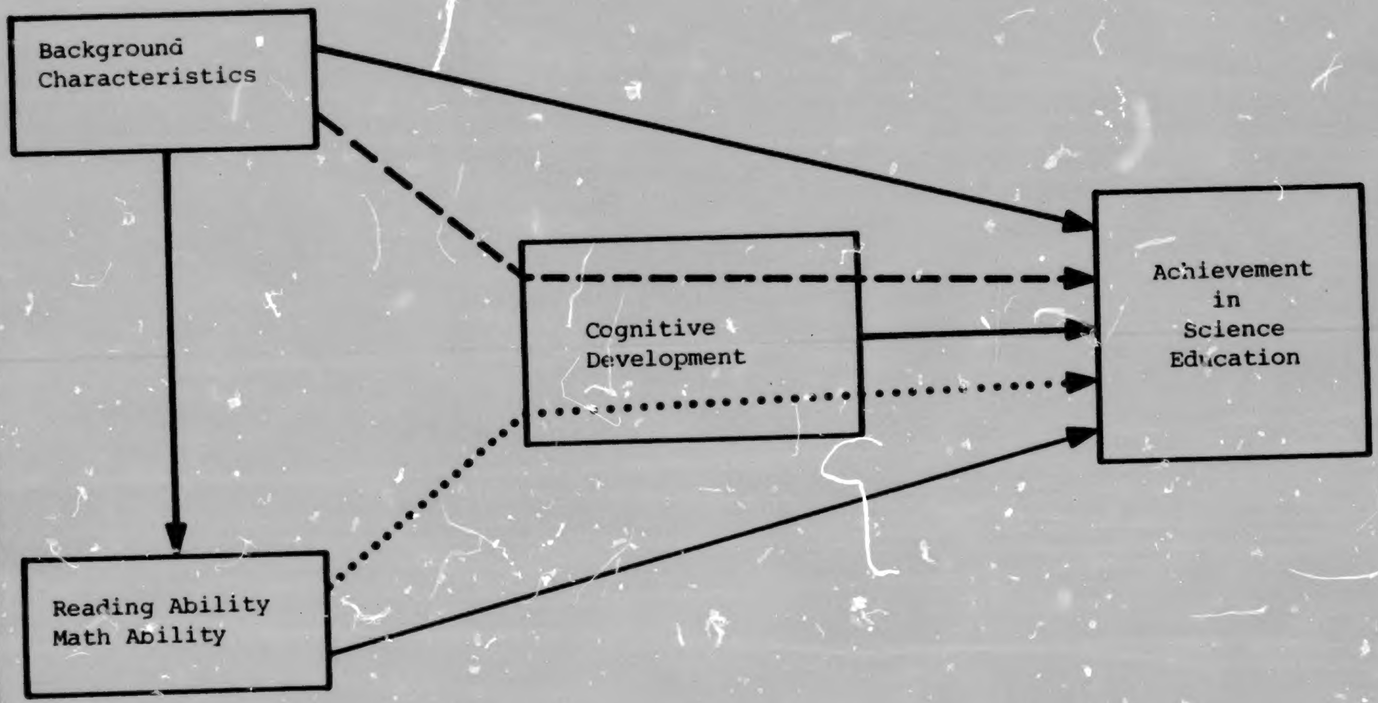

Background Characteristics
Cognitive Development
Achievement in Science Education
Reading Ability
Math Ability

Figure 4. Paradigm.

The remaining variables are endogenous variables. The variance of endogenous variables is assumed to be completely explained by exogenous and endogenous variables in the system. In Figure 4, Reading Ability and Math Ability, Cognitive Development and Achievement in Science Education are endogenous variables. An endogenous variable such as Cognitive Development can be treated as a dependent variable in relation to Background Characteristics and Reading and Math Ability. Cognitive Development can also be treated as an independent variable in relation to Achievement in Science Education.

Each dependent variable can be represented by an equation which consists of the variables upon which the dependent variable is assumed to be dependent and a term representing all other factors not under consideration in the model (residuals). "It is convenient not to represent residuals in the diagrams (Kerlinger, 1973:309)." The residuals are presented in Table 21.

Within the model, the correlations between two variables can be decomposed into that part of the correlation which is due to the direct effect of a cause and that part of the correlation which is due to the indirect effect of a cause. For example, the causal equation for the total effect of the variable, race, on achievement in science education is: $r_{15} = p_{15} + p_{12}r_{25} + p_{13}r_{35} + p_{14}r_{45} + p_{16}r_{56} + p_{17}r_{57} + p_{18}r_{58}$. The direct effect of

Table 21. Path Analysis Residuals

Variable	Residuals[a]
Reading Ability	0.87
Math Ability	0.88
Cognitive Development	0.75
Achievement in Science Education	0.89

[a] The formula for calculating the residuals is $\sqrt{1 - R^2}$.

race on achievement in science education is p_{15}. The other causal paths are the indirect effects.

The paradigm previously presented is a simplified paradigm (Figure 4). However, the box representing the term, background characteristics, is, in reality, a composite of all the background characteristics whose null hypotheses were rejected - race, mothers' occupation, fathers' education and number of siblings. The box representing reading and math ability is, in reality, a composite of reading ability and math ability. Figure 5 was the paradigm used for the path analysis.

Solutions for the direct effect and the total indirect effects of a variable such as cognitive development on another variable such as achievement in science education were accomplished in two steps. Step One calculates the direct effect and Step Two calculates the Total Indirect Effects (TIE).

The direct effect was determined from the beta of each variable in the multiple regression equation of achievement in science education. "It is customary to use the standardized betas as the path coefficients (Land, 1969)."

The betas obtained by the multiple linear regression were partial betas. A partial beta is a beta of one variable in an equation with all the other variables in the equation held constant. This beta is then the path

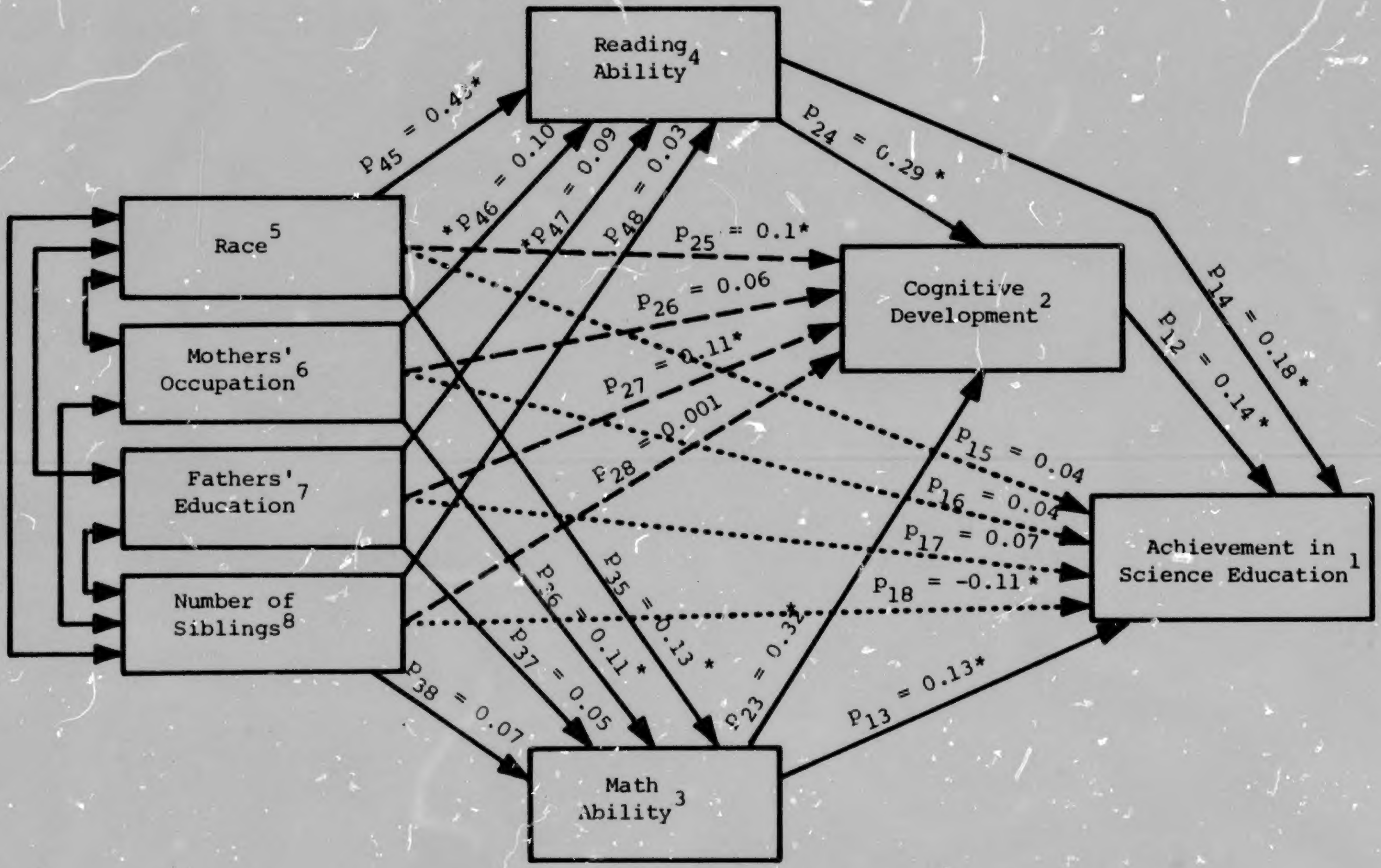

Reading Ability 4
Race 5
Mothers' Occupation 6
Fathers' Education 7
Number of Siblings 8
Cognitive Development 2
Math Ability 3
Achievement in Science Education 1
P45 = 0.43*
*P46 = 0.10
*P47 = 0.09
P48 = 0.03
P24 = 0.29 *
P25 = 0.1*
P26 = 0.06
P27 = 0.11*
P28 = 0.001
P14 = 0.18*
P12 = 0.14*
P15 = 0.04
P16 = 0.04
P17 = 0.07
P18 = -0.11 *
P35 = 0.13 *
P36 = 0.11 *
P37 = 0.05
P38 = 0.07
P23 = 0.32*
P13 = 0.13*

Figure 5. Path Analysis Paradigm.

coefficient which is equal to the direct effect of that variable on the dependent variable.

The betas from the multiple linear regression of race, mothers' occupation, fathers' education, number of siblings, reading ability, math ability and cognitive development on achievement in science education are presented in Table 22.

Therefore, the direct effect of cognitive development on achievement in science education is 0.14. The direct effect of math ability on achievement in science education is 0.13. The direct effect of reading ability on achievement in science education is 0.18. The direct effect of the background characteristics on achievement in science education are:

Background Variable	Direct Effect
Race	0.04
Mothers' Occupation	0.04
Fathers' Education	0.07
Number of Siblings	-0.11

Figure 5 shows the path analysis paradigm with all the path coefficients. The path coefficients not considered in this research study are shown in the path analysis for clarification of the entire analysis. These path coefficients were obtained from the appropriate multiple regression equations.

Table 22. Partial Betas of Achievement in Science Education.

Variable	Beta	Path Coefficient
Race	0.04069	0.04
Mothers' Occupation	0.03704	0.04
Fathers' Education	0.06855	0.07
Number of Siblings	-0.10881	-0.11
Reading Ability	0.18140	0.18
Math Ability	0.13177	0.13
Cognitive Development	0.13951	0.14

In the second step which determined the Total Indirect Effects, (TIE), of a variable, "all that is necessary is to subtract the direct effect from the correlation coefficient between it and the dependent variable (Kerlinger, 1973: 317)."

Therefore, to determine the total indirect effects of cognitive development, the direct effect of cognitive development (0.14) is subtracted from the correlation coefficient (0.36). The correlation coefficient of cognitive development and achievement in science education is shown in the correlation matrix as presented in Table 23. The TIE of background characteristics and reading and math ability is:

$$\begin{aligned} \text{TIE} &= 0.36 - 0.14 \\ &= 0.22 \end{aligned}$$

The indirect effect of cognitive development on achievement in science education (0.22) are spurious effects because they are a consequence of the variables, cognitive development, reading ability and math ability having a common cause, the background characteristics. Though 0.22 is a spurious indirect effect, the other variables do have legitimate indirect effects on achievement in science education operating through cognitive development.

The indirect effect of reading ability on achievement in science education through cognitive development

Table 23. Correlation Matrix.

	Race	Mothers' Occupation	Fathers' Education	Number of Siblings	Reading Ability	Math Ability	Cognit Develop
Mothers' Occupation	-0.0762						
Fathers' Education	-0.1242	0.2452	-0.1292				
Number of Siblings	0.0055	-0.1030	-0.1292				
Reading Ability	-0.1120	0.1950	0.2109	-0.0234			
Math Ability	-0.0760	0.1956	0.1800	-0.0250	0.6356		
Cognitive Development	-0.1222	0.2274	0.2728	-0.0687	0.5737	0.5804	
Achievement	-0.0679	0.1621	0.1950	-0.0922	0.3884	0.3594	0.361

can be obtained from the path coefficients $p_{24}p_{12}$ (p_{12} = 0.14, p_{24} = 0.29). The indirect effect is 0.04.

The indirect effect of math ability on achievement in science education through cognitive development can be determined from the path coefficients, $p_{23}p_{12}$ (p_{12} = 0.4, p_{23} = 0.32). The indirect effect is 0.05.

The indirect effect of race on achievement in science education through cognitive development is $p_{25}p_{12}$ = 0.014. The indirect effect of mothers' occupation on achievement in science education through cognitive development is $p_{26}p_{12}$ = 0.008. The indirect effect of fathers' education on achievement in science education mediated by cognitive development is $p_{27}p_{12}$ = 0.02. The indirect effect of number of siblings on achievement in science education mediated by cognitive development is $p_{26}p_{12}$ = 0.0001.

As can be seen from Figure 5, many path coefficients, such as race, mothers' occupation and fathers' education to achievement in science education, are small and insignificant. (The path coefficients in Figure 5 which are significant are indicated with an *.) If these insignificant paths were eliminated, the path analysis mode would be a more parasimonious model.

Summary.

This chapter showed the relationships between the General Biology students' background characteristics, their reading and math ability and their cognitive development level to their achievement in science education using multiple regression. Path analysis was used to show that cognitive development was a mediating variable between background characteristics and reading and math ability. The summary, conclusions, discussion and recommendations of this study are presented in Chapter V.

CHAPTER V

SUMMARY, CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

Summary.

This research study was undertaken to identify the background characteristics of students enrolled in a General Biology course at WC_3. It was designed to formulate a predictive equation which could be utilized to identify those students who most probably would not succeed in science education at a large, urban community college.

The purposes of this study were to:

(1) Examine and analyze the students' background characteristics and their reading and math abilities as they relate to the students' cognitive development.

(2) Examine and analyze the students' background characteristics and their reading and math ability as they relate to the students' achievement in science education.

(3) Examine and analyze the students' cognitive development as it acts as a mediating variable between the students' background characteristics, and their reading and math ability with their achievement in science education.

(4) Establish a predictive equation to identify students who may not succeed in science education.

Data were collected on 420 students in the WC_3 regional system. Instruments used were:

(1) The College Biology Student Survey.

(2) The Inventory of Piaget's Developmental Tasks (IPDT).

(3) The CGP Applied Arithmetic Placement Test (CGP).

(4) The Nelson Denny Reading Test, Form F.

(5) Achievement in science education was determined by the letter grade assigned by the instructors.

These instruments were administered by this researcher to General Biology students during the Fall Semester, 1981. The data collected were used in the statistical analyses.

Data Analysis.

The descriptive statistics showed that the WC_3 General Biology student classes were racially balanced, 49% white and 51% non-white. The median age was 26. Females comprised 82% of the sample. Seventy-one percent of the students were single, divorced, separated or widowed while 29% were married. From an 80% response rate of students who knew their parents' occupation, 45% of the fathers had a blue collar job; 35% had a white collar job. Approximately 50% of the mothers worked full or part-time, the majority had service related or clerical jobs. From an 85%

response rate of students who knew their parents' level of formal education, 34% of the parents did not finish high school, 27% of the mothers and 19% of the fathers graduated from high school, 23% of the fathers and 26% of the mothers had formal schooling beyond high school either in a technical school, community college, college or university. The students had a twelfth grade reading level. The average score on the CGP was 15 correct answers out of a possible 25 correct answers. The average score on the IPDT was 49 correct items out of a possible 72 correct choices. Only 68% of these items were answered correctly. The students' average grade was 2.7 (C+).

Simple regressions were calculated on each of the background characteristics, sex, age, race, marital status, parents' occupation, parents' education, and number of siblings with the students' total score on the IPDT, each of the five problem area skills identified in the IPDT (see Chapter I), and the students' achievement in science education. Only those background characteristics whose null hypotheses were rejected were used in the multiple linear regressions.

Null hypotheses were constructed for the first eight research hypotheses. The α was set at 0.05. Multiple linear regressions were computed to test these hypotheses.

Research Hypothesis One: A positive and direct relationship exists between the students' background characteristics and the cognitive skills that students have attained.

> Hypothesis 1a: There is no significant difference between the students' background characteristics and the total score on the IPDT.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The variables, sex, race, marital status, fathers' occupation and parents' education accounted for 25.6% of the variance of cognitive development. The F-ratio was 5.055 ($\alpha = 0.00$).

> Hypothesis 1b: There is no significant difference between the students' background characteristics and their ability in each of the five problem area skills.

The null hypothesis was rejected indicating that the research hypothesis was accepted. This researcher ranked the five problem area skills from those skills showing the highest variance attributed to background characteristics to those skills showing the least variance:

F-ratio ($\alpha = 0.00$)

1.	Proportional Reasoning	4.923	22.5% variance
2.	Imagery	6.011	16% variance
3.	Conservation	5.774	15% variance
4.	Classification	2.848	9% variance
5.	Relations	2.115	7.4% variance

Research Hypothesis Two: A positive and direct relationship exists between the students' background characteristics and their achievement in science education.

> Hypothesis 2: A positive and direct relationship exists between the students' background characteristics and their achievement in science education.

The null hypothesis was rejected indicating the research hypothesis was accepted. The background characteristics, marital status, race, fathers' education, mothers' occupation and number of siblings accounted for 9.6% of the variance of achievement in science education. The F-ratio was 3.613 ($\alpha = 0.00$).

Research Hypothesis Three: A positive and direct relationship exists between the students' reading and math ability and the cognitive skills the students have attained.

Hypothesis 3a: There is no significant difference between the linear additive effects of the students' reading and math ability and their total score on the IPDT.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 141.782 (α = 0.00). Reading and math ability explained 40% of the variance of the total score of the IPDT.

Hypothesis 3b: There is no significant difference between the linear additive effect of the students' reading and math ability and their ability in each of the five problem area skills.

The null hypothesis was rejected indicating that the research hypothesis was accepted. This researcher ranked the five problem area skills from those skills showing the highest variance attributed to reading and math ability to those skills showing the least variance:

		F-ratio (α = 0.00)	
1.	Imagery	68.439	24.4% variance
2.	Proportional Reasoning	61.330	22% variance
3.	Conservation	46.720	18% variance
4.	Relations	38.465	15% variance
5.	Classification	29.715	12% variance

Research Hypothesis Four: A positive and direct relationship exists between the students' reading and math ability and their achievement in science education.

> Hypothesis 4: There is no significant difference between the students' reading and math ability and their achievement in science education.

The null hypothesis was rejected indicating the research hypothesis was accepted. The F-ratio was 43.809 ($\alpha = 0.00$). Reading and math ability explained 17% of the variance of achievement in science education.

Research Hypothesis Five: A positive and direct relationship exists between the students' cognitive skills and their achievement in science education.

> Hypothesis 5: There is no significant difference between the students' total score on the IPDT and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 6.2714 ($\alpha = 0.00$). Cognitive development as measured by the IPDT explained 12.8% of the variance of achievement in science education.

Research Hypothesis Six: A positive and direct relationship exists between the students' background characteristics, their cognitive development and their achievement in science education.

> Hypothesis 6: There is no significant difference between the linear, additive effects of the students' background characteristics, their cognitive development and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 5.792 ($\alpha = 0.00$). The linear additive effect of background characteristics and cognitive development explained 17% of the variance of achievement in science education.

Research Hypothesis Seven: A positive and direct relationship exists between the students' reading and math ability, their cognitive development and their achievement in science education.

> Hypothesis 7: There is no significant difference between the linear, additive effects of the students' reading and math ability, their cognitive development and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 32.762 ($\alpha = 0.00$). The linear additive effect of background characteristics, reading and math ability and cognitive development explained 18.6% of the variance of achievement in science education.

Research Hypothesis Eight: A positive, direct additive linear relationship exists between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

> Hypothesis 8: There is no significant difference between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 6.753 ($\alpha = 0.00$). The linear additive effect of background characteristics, reading and math ability and total score on the IPDT explained 22% of the variance of achievement in science education.

Research Hypothesis Nine was examined using path analysis. Path analysis is a statistical technique used to "determine whether or not a pattern of correlations for a set of observations is consistent with a specific theoretical formulation (Kerlinger, 1973:317)."

Research Hypothesis Nine: Cognitive development is a mediating variable between the independent variables, background characteristics, reading and math ability and the dependent variable, achievement in science education.

> Hypothesis 9a: There is a direct effect of cognitive development on achievement in science education independent of the overlapping effects of background characteristics, reading and math ability.
>
> The direct effect of cognitive development established by the path coefficient was 0.14.
>
> Hypothesis 9b: There are direct effects of background characteristics, reading ability and math ability on achievement in science education.
>
> The direct effects of the background characteristics on achievement in science education were: race - 0.04, mothers' occupation - 0.04, fathers' education - 0.07, and number of siblings - -0.11. The direct effects of reading ability on achievement in science education was

0.18. The direct effect of math ability on achievement in science education was 0.13.

Hypothesis 9c: There are indirect effects on the background characteristics, reading ability and math ability on achievement in science education mediated by cognitive development.

The indirect effects of background characteristics on achievement in science education mediated by cognitive development were: race - 0.014, mothers' occupation - 0.008, fathers' education - 0.02, and number of siblings - 0.0001. The indirect effect of reading ability on achievement in science education mediated by cognitive development was 0.04. The indirect effect of math ability on achievement in science education mediated by cognitive development was 0.05.

Conclusions.

The following conclusions were made while recognizing the limitations of the study.

The demographic data obtained from the test instruments showed that the General Biology classes had a higher percentage of females (82%) than males (18%). The students' median age was 26. The classes were racially balanced (49% white, 51% non-white). The majority of the students (71%) were single or formerly married. From an 85% response rate of students who knew their parents' level of formal education, 34% of the parents did not finish high school, 27% of the mothers and 19% of the fathers graduated from high school and 23% of the fathers and 26% of the mothers had formal schooling beyond high school. Forty-five percent of the fathers were employed in blue collar jobs and 35% had white collar jobs. Of those mothers employed (51%), the majority were in service related or clerical jobs. The average math score of the students was 15 correct answers out of 25 possible choices. The students' average reading ability was twelfth grade. Their average score on the IPDT was 49 correct items out of a possible 72 correct items. Only 9% of the students were at the formal level of cognitive development, while 91% were at the concrete level of cognitive development. The average grade was 2.7 (C+).

The conclusions inferred from the data are summarized according to the purposes of the study.

The background characteristics, reading and math ability are positively related to the students' cognitive development. Knowing the sex, marital status, mothers' occupation, fathers' education, their reading level and their math ability accounted for 42.5% of the variance in the students' cognitive development.

The background characteristics, reading and math ability are positively related to the students' achievement in science education. Knowing the sex, marital status, mothers' occupation, fathers' education, their reading level and their math level accounted for 43% of the variance in the students' achievement in science education.

Cognitive development accounted for 12.8% of the variance in the students' achievement in science education. With cognitive development as a mediating variable, the background characteristics and the students' reading and math ability accounted for 22% of the variance in achievement in science education. An equation which could identify students who may not succeed in science education can be formulated using the following factors: race, mothers' occupation, fathers' education, number of siblings, reading ability, math ability, cognitive development skills and marital status.

$$Y' = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6H_6 + b_7X_7 + b_8X_8$$

If

X_1 = cognitive development
X_2 = reading ability
X_3 = math ability
X_4 = race
X_5 = mothers' occupation
X_6 = fathers' education
X_7 = number of siblings
X_8 = marital status

then with the appropriate b's and the Y-intersect (a) the formula would read:

$$Y' = 0.42 + 0.14X_1 + 0.18X_2 + 0.13X_3 + 0.04X_4 + 0.04X_5 + 0.07X_6 + -0.11X_7 + -0.06X_8$$

It must be remembered that this equation is based on group data and predication error for an individual student may be sizable.

Discussion.

Background Characteristics and Cognitive Development. According to the literature, the students' level of cognitive development depends on many factors which can be considered background characteristics: age, sex, race and parental level of education. In this study age had no effect on cognitive development. The null hypothesis was accepted. The fact that 61% of the students are 22 or older may account, in part, for this phenomenon. There could be a leveling effect because the majority of the students are older.

The explained variance attributed to sex ranged from 0% on the problem area skills, Relations and Classification to 5% on the problem area skill, Proportional Reasoning. The amount of variance of the total score explained by sex is 2.4%. Considering the importance it is given in the literature, this variable explains a small amount of the variance. However, 82% of the General Biology students are female. This high ratio of females to males could dampen or level off the effect of sex on the students' cognitive development.

Race accounted for the greatest amount of variance in cognitive development. Forty-nine percent of the students are white, 51% are non-white. In examining the five problem area skills, whites attained more cognitive skills in all five problem area skills.

Background Characteristics and Achievement in Science Education. The background characteristics, race, marital status, mothers' occupation, fathers' education and number of siblings, contributed to the amount of explained variance of achievement in science education.

In the literature, some researchers found no significant relationship between sex and achievement while others found a significant relationship. In this research study, sex was not significantly related to achievement. By examining a bivariate frequency table, the percentage of females to males achieving A's, B's, C's, D's and E's showed only a maximum of 2% difference. Therefore, this researcher would have to conclude that sex was not significantly related to achievement in science education.

Age was not significantly related to achievement in this research study. The literature on achievement in community college found that older, married women achieved higher than any other groupings of students. Due to a higher percentage of older students (61%) in this study, a leveling effect may have occurred.

Race was the background characterisic which explained the greatest amount of the variance (7%) of achievement from all the background characteristics. White students achieved better than non-white students. This researcher found no literature regarding the effect of race on science achievement in community college students. However, the literature on student achievement in community college suggests that race would not be a factor in achievement. This discrepancy between the literature and the research results may be accounted for because WC_3 serves such a range of students and the lower income black students are clustered at two campuses.

This research study agreed with the literature that marital status has a significant relationship to achievement in science education. There was a higher percentage of married students (87%) passing the course than single students (79%).

Cognitive Development, Math Ability and Achievement. The average score of the IPDT was 49. This means that on the average only 68% of the items were answered correctly. Upon examining the five problem area skills, Relations, Imagery, Conservation, Classification and Proportional

Reasoning, 59% of the students have the cognitive skill, Relations; 37% have the cognitive skill, Imagery; 18% have the cognitive skill, Conservation; 9% have the cognitive skill, Classification and 11% have the cognitive skill, Proportional Reasoning.

Few students have all of those cognitive skills and could be classified as being at Piaget's formal level of cognitive development. In fact, the majority of the students have, at best, two of the cognitive skills. The students as a group must be considered to be at the concrete level of cognitive development. These test results agree with the results of other studies. The majority of students (adults) have not reached the formal level of cognitive development.

Those cognitive skills, Conservation, Classification and Proportional Reasoning, which require math ability, have the smallest number of students as having attained these skills (18%, 9%, 11%, respectively). When the students' math ability is examined, only 16% of the students answered 20 or more questions correctly on the CGP. Since the CGP has 25 questions on elementary math, it must be concluded that the WC_3 General Biology students are deficient in math. This math deficiency also affects their cognitive skills. If they cannot use ratios, they cannot reason proportionally.

The lack of math ability can affect their achievement in science education. The General Biology course covers topics such as chemical equations, metrics, and genetic problems, all of which require math ability to understand.

In the past, students have had great difficulty solving genetic problems which are based on ratio and proportions. Their lack of math ability partially explains their inability to solve these problems. Teaching the metric system is a morass into which both teachers and students slowly sink. Lack of math ability directly influences the students' inability to understand the metric system. Consequently, lack of math ability adversely affects the students' cognitive development and achievement in science education.

Achievement.

The number of students (67%) earning a B or better in General Biology seemed high. A number of factors could account for this high rate of achievement. The grades could be inflated since teachers made their own tests and standardized tests were not given. Marginal or failing students may not have participated in the study. Thus, insufficient data from these marginal students could have inflated the grades. The students' reading level may play a more important role than math ability on achievement.

The students had a twelfth grade reading level, but only 16% could correctly answer 20 or more problems correctly out of 25 possible choices on a math test approximately sixth grade level. Conversely, math ability played a more important role in cognitive development. And, perhaps, the high grades could be attributed to good teaching.

Recommendations.

This research study determined that the majority of WC_3 College General Biology students are at the concrete level of cognitive development. Most college biology courses are taught at the formal level of cognitive development. This discrepancy between the students' level of cognitive development and the teachers' level of instruction can lead to teacher and student frustration, drop-outs and a continuation of the self-fulfilling prophecy of failure.

Since most instructors will be hesitant or adamant about changing their method of instruction, other ways can be found to enhance the students' achievement.

Teaching models, audio-visual aids and self-paced learning modules can be made available for students' use in the Learning Resource Center.

Since WC_3 has numerous computer terminals in specially equipped rooms staffed with computer lab assistants, computer assisted instruction (CAI) for units such as the metric system, chemical formulas and equations, genetic problems and ecology simulations could be available for students. Computer practice tests to alleviate test anxiety could also be available.

Students can be encouraged to utilize more effectively and efficiently the Student Services. These services include tutoring, mini courses in developing study skills and test skills using biofeedback techniques.

Exposure to additional "hands on" exercises in the biology labs could enhance cognitive development and thus achievement in science education. For example, special emphasis could be placed on hierarchial classification through the use of dichtomous keys; reversibility and proportional reasoning could be demonstrated using the metric system and genetic problems; combinatorial reasoning could be aided using several variables and control systems in photosynthetic experiments, organic compound experiments and enzyme experiments.

Though WC_3 is a community college with an open-door policy, the lack of diagnostic tests permits students to enroll in classes for which they are not academically skilled. The test instruments from this research study can be utilized as a diagnostic measure. They can assess the students' academic strengths as well as their academic weaknesses. The counselors/instructors can then direct the student to the appropriate remedial classes if necessary.

The results of the research study indicate that high risk students who are at the concrete level of cognitive development would benefit from the development of a remedial course which would emphasize reading, math and study skills in a biological framework. This type of remedial course would help develop the students' academic skills. By stressing skills necessary for scholastic achievement, this course would benefit the high risk student not only in future biology courses but other academic areas as well. It is unfortunate that students enter the community college scholastically unprepared. Conceptually, the students' skill deficiencies can be traced to their elementary schooling. To prevent underprepared community college students, the elementary school must provide students with cognitive skills development. This can be best accomplished through properly utilizing their science classes to stress skills in math, reading and reasoning.

Future research studies could be conducted on other pre-requisite science classes, such as General Chemistry and General Physics. The data from students enrolled in these courses could be compared with the data from students in the General Biology course noting similarities and differences in cognitive skills and achievement.

Studies could also be conducted on advanced science classes to determine if exposure to additional science classes increases the students' cognitive skills and lower their failure rate.

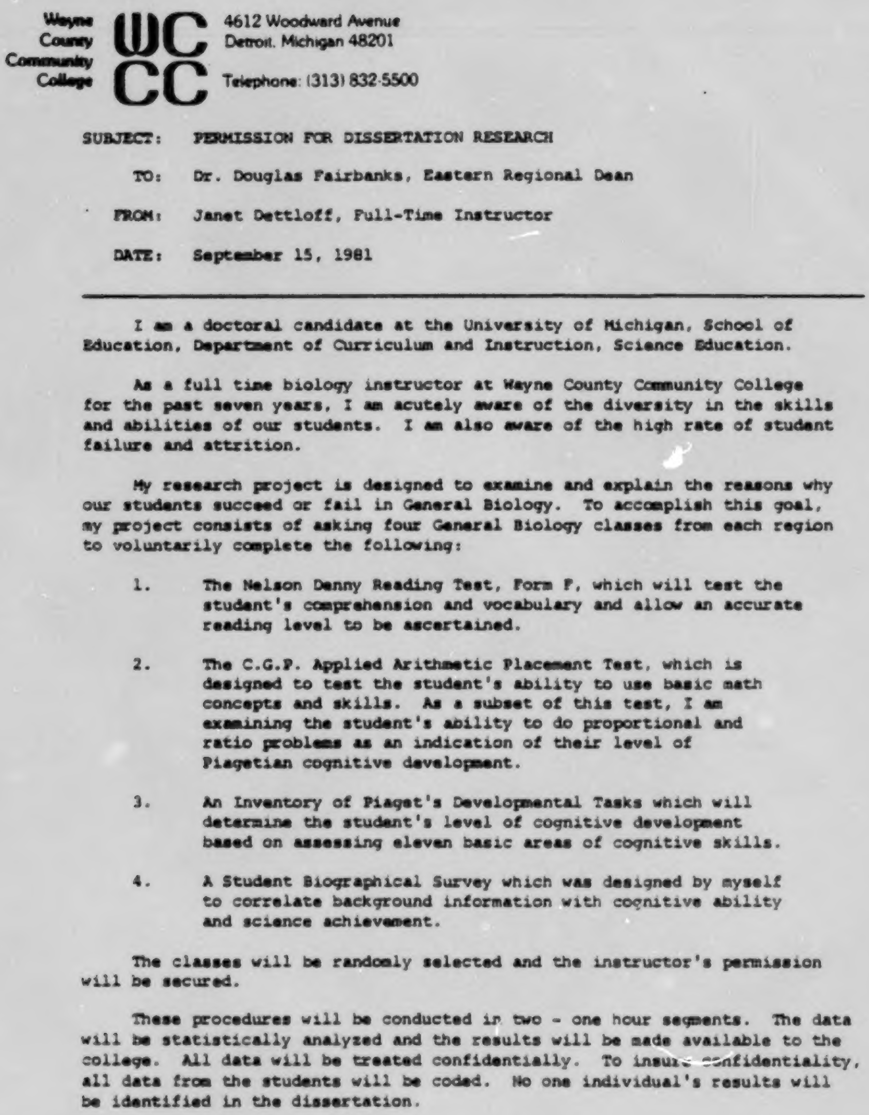
If these test measures were used as a diagnostic measure prior to enrollment, those students identified as high risk could then be offered the option of taking the remedial skills course before enrolling in the Biology course.

Proper utilization and interpretation of these test measures could help prevent the open door from becoming a revolving door.

APPENDICES

APPENDIX A

REQUEST FOR PERMISSION FOR RESEARCH STUDY



Wayne County Community College WCCC
4612 Woodward Avenue
Detroit, Michigan 48201
Telephone: (313) 832-5500

SUBJECT: PERMISSION FOR DISSERTATION RESEARCH

TO: Dr. Douglas Fairbanks, Eastern Regional Dean

FROM: Janet Dettloff, Full-Time Instructor

DATE: September 15, 1981

I am a doctoral candidate at the University of Michigan, School of Education, Department of Curriculum and Instruction, Science Education.

As a full time biology instructor at Wayne County Community College for the past seven years, I am acutely aware of the diversity in the skills and abilities of our students. I am also aware of the high rate of student failure and attrition.

My research project is designed to examine and explain the reasons why our students succeed or fail in General Biology. To accomplish this goal, my project consists of asking four General Biology classes from each region to voluntarily complete the following:

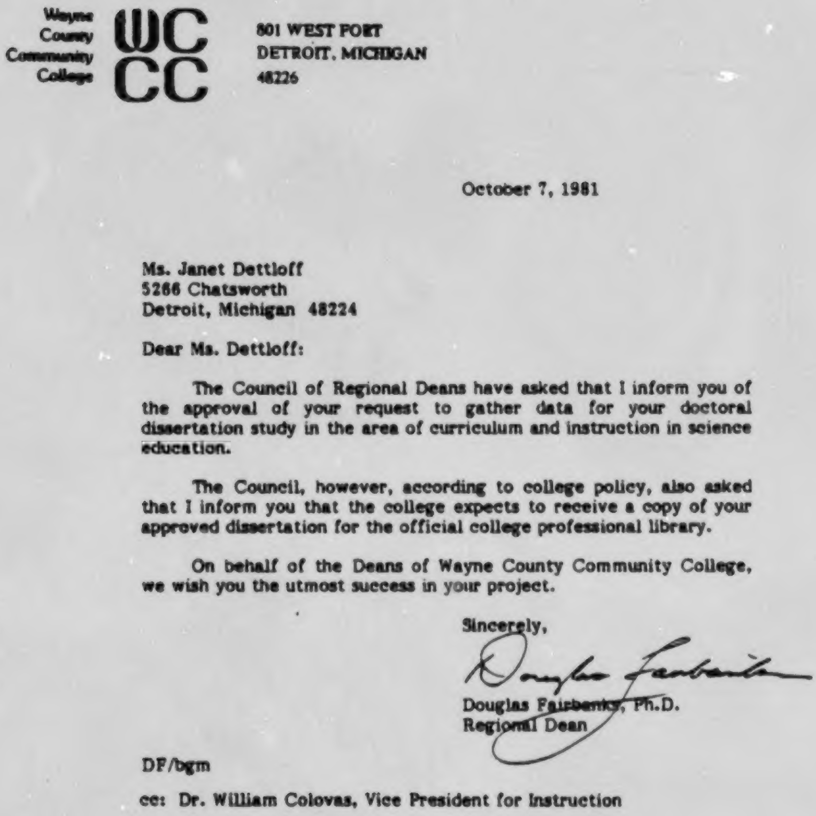
1. The Nelson Denny Reading Test, Form F, which will test the student's comprehension and vocabulary and allow an accurate reading level to be ascertained.
2. The C.G.P. Applied Arithmetic Placement Test, which is designed to test the student's ability to use basic math concepts and skills. As a subset of this test, I am examining the student's ability to do proportional and ratio problems as an indication of their level of Piagetian cognitive development.
3. An Inventory of Piaget's Developmental Tasks which will determine the student's level of cognitive development based on assessing eleven basic areas of cognitive skills.
4. A Student Biographical Survey which was designed by myself to correlate background information with cognitive ability and science achievement.

The classes will be randomly selected and the instructor's permission will be secured.

These procedures will be conducted in two - one hour segments. The data will be statistically analyzed and the results will be made available to the college. All data will be treated confidentially. To insure confidentiality, all data from the students will be coded. No one individual's results will be identified in the dissertation.

APPENDIX B

APPROVAL OF RESEARCH STUDY



Wayne
County
Community
College
WC
CC

801 WEST FORT
DETROIT, MICHIGAN
48226

October 7, 1981

Ms. Janet Dettloff
5266 Chatsworth
Detroit, Michigan 48224

Dear Ms. Dettloff:

The Council of Regional Deans have asked that I inform you of the approval of your request to gather data for your doctoral dissertation study in the area of curriculum and instruction in science education.

The Council, however, according to college policy, also asked that I inform you that the college expects to receive a copy of your approved dissertation for the official college professional library.

On behalf of the Deans of Wayne County Community College, we wish you the utmost success in your project.

Sincerely,

Douglas Fairbanks

Douglas Fairbanks, Ph.D.
Regional Dean

DF/bgm

cc: Dr. William Colovas, Vice President for Instruction

APPENDIX C

RANDOM SELECTION PROCEDURES

The method used to select the classes randomly was:

1. List all the General Biology classes by region.
2. Using the first two numbers on a dollar bill, flip a quarter to determine whether the first or second number was used to enter the random number table. A separate dollar bill was used for each region.
3. Consult the random number table until a different one digit number for each class was assigned at each region.
4. Place all the numbers in a jar. Shake well. Draw out one number. Select the class corresponding with that number. Return the number to the jar.
5. Follow the same procedure for all regions except the Western Region, which has only four classes.

APPENDIX D

THE COLLEGE BIOLOGY STUDENT SURVEY

**Wayne
County
Community
College**

**College Biology
Student Survey**

Social Security Number________________

PUT YOUR ANSWERS ON THIS QUESTIONNAIRE

DIRECTIONS

Please circle the number or numbers of the answer(s) and fill in the blanks for the appropriate questions. Ignore the numbers on the right-hand side of the page.

1. Indicate your sex: (11)
   1. Male
   2. Female
2. Indicate your age: (12)
   1. 17 - 22
   2. 23 - 30
   3. 31 - 40
   4. 41 - 50
   5. Over 50
3. Indicate your race: (13)
   1. White
   2. Black
   3. Arabian
   4. Hispanic
   5. Oriental
   6. Other (please specify)________________________
4. Are you: (14)
   1. Single
   2. Married
   3. Living together
   4. Separated, Divorced, Widowed

5. Did you attend high school at any time? (15)

   1. Yes

   2. No

6. Did you graduate from high school? (16)

   1. Yes

   2. No

IF YOUR ANSWER TO QUESTION 6 IS NO, THEN ANSWER QUESTIONS 7, 8, AND 9.

IF YOUR ANSWER TO QUESTION 6 IS YES, THEN GO TO QUESTION 10.

7. What was the last grade you attended in high school? (17)

   1. Freshman - grade 9

   2. Sophomore - grade 10

   3. Junior - grade 11

   4. Senior - grade 12

8. Did you take the GED (General Education Diploma)? (18)

   1. Yes

   2. No

9. Did you pass the GED? (19)

   1. Yes

   2. No

10. Indicate how long it was from the time you completed or left high school until you started college (any college, including WC_3): (20)

    1. Less than 1 year

    2. One to five years

    3. Six to ten years

    4. Eleven to fifteen years

    5. More than fifteen years.

11. Since you first attended college (any college), did you stop attending college and then return (excluding summer vacation)? (21)

    1. Yes

    2. No

IF YOUR ANSWER TO QUESTION 11 IS YES, THEN ANSWER QUESTIONS 12, 13, AND 14.

IF YOUR ANSWER TO QUESTION 11 IS NO, THEN GO TO QUESTION 15.

12. How many years were you out of college before returning to college? (22-23)

    ______________ years

13. How many years have you attended college either full- or part-time since you left high school? (Do NOT include the time you were not in college.) (24-25)

    ______________ years

14. List your occupation(s) (for example, factory worker, sales-clerk, clerical, etc.) during the time(s) you were not in college: (26-28)

Occupation	Dates
______________	______________
______________	______________
______________	______________
______________	______________

15. Indicate the number of credit hours you are taking this semester: (29)

    1. 4

    2. 5 - 8

    3. 9 - 11

    4. 12 - 17

    5. Over 17

16. Are you working now? (30)

    1. Yes

    2. No

IF YOUR ANSWER TO QUESTION 16 IS YES, THEN ANSWER QUESTIONS 17 AND 18.

IF YOUR ANSWER TO QUESTION 16 IS NO, THEN GO TO QUESTION 19.

17. Indicate the number of hours you work per week: (31)

    1. 1 - 10 hours
    2. 11 - 20 hours
    3. 21 - 30 hours
    4. 31 - 40 hours
    5. Over 40 hours

18. Indicate your current occupation (excluding student): (32)

    ____

19. Do you live: (33)

    1. At home with your parents
    2. With a mate (husband/wife/roommate(s))
    3. Alone

20. Do you have children? (34)

    1. Yes
    2. No

IF YOUR ANSWER TO QUESTION 20 IS YES, THEN ANSWER QUESTIONS 21 AND 22.

IF YOUR ANSWER TO QUESTION 20 IS NO, THEN GO TO QUESTION 23.

21. Indicate the number of children living with you: (35-36)

    ____

22. How many of these children are dependent on you for their support? (37-38)

    ____

23. What was your total family income in 1980 before taxes and deductions? (39)

    1. 0 - $4,999
    2. $5,000 to $9,999
    3. $10,000 to $14,999
    4. $15,000 to $19,999
    5. $20,000 and over

24. Indicate all the financial resource(s) that enable you to attend WC_3 and meet your living expenses: (40-45)

    1. Support from parents
    2. Earnings from job
    3. Support from spouse/mate
    4. Student loan
    5. Veteran's Bill
    6. BEOF (Basic Educational Opportunity Grant) or Pell Grant
    7. Scholarship
    8. Michigan Opportunity Grant
    9. Other state and federal government sources (ADC, Social Security, etc.)
    10. Other (please specify) ____________________________

25. Indicate your father's occupation. If your father is retired or deceased, indicate his major occupation while employed: (46)

    ____

26. Is your mother employed now, or was she previously, employed? (47)

    1. Yes, full-time
    2. Yes, part-time
    3. No.

27. If yes, indicate your mother's occupation: (48)

    ____

28. Indicate how much schooling (formal education) your parents or the persons who raised you have. Check the blank that applies for the Male/Father and the Female/Mother: (49) (50)

Male/Father		Female/Mother
________	Grade school	________
________	Some high school	________
________	Finished high school	________
________	Technical school	________
________	Some college	________
________	Associate degree	________
________	Bachelor's degree	________
________	Graduate school	________
________	Don't know	________

29. Indicate the number of brothers and sisters you have. Include adopted/step/half brothers and sisters: (51-52) (53-54)

1. Brothers ____________
2. Sisters ____________
3. None ____________

IF YOUR ANSWER TO QUESTION 29 IS NONE, THEN GO TO QUESTION 34.

30. How many of your brothers and sisters finished high school? (55) (56)

1. Brothers ____________
2. Sisters ____________

31. How many of your brothers and sisters plan to attend college? (57) (58)

1. Brothers ____________
2. Sisters ____________

32. How many of your brothers and sisters are currently attending college? (59) (60)

1. Brothers ______________
2. Sisters ______________

33. How many of your brothers and sisters have finished college? (61) (62)

1. Brothers ______________
2. Sisters ______________

34. Indicate all the math classes taken and passed WHILE ATTENDING HIGH SCHOOL:

Math Classes	Taken	Passed (Yes or No)	(63-70) (71-77)
Refresher Math	____	________	
Basic/General Math	____	________	
Business Math	____	________	
Bookkeeping	____	________	
Pre-algebra	____	________	
First year Algebra	____	________	
Second year Algebra	____	________	
First year Geometry	____	________	
Second year Geometry	____	________	
Trigonometry	____	________	
Pre-calculus	____	________	
Calculus	____	________	
Computer Math	____	________	

Other (please specify) ____

35. Indicate all the science classes taken and passed WHILE ATTENDING HIGH SCHOOL: (5- 9) (10-14)

Science Classes	Taken	Passed (Yes or No)
Physical Science		
General Science		
Earth Science		
Biology		
Chemistry		
Physics		

36. Indicate all the math classes (basic arithmetic, algebra, etc.) taken and passed WHILE ATTENDING COLLEGE, ADULT EDUCATION CLASSES, TECHNICAL OR BUSINESS SCHOOL: (15-19) (18-2

Math Classes Taken	Passed (Yes or No)

37. Indicate all the science courses (hygiene, chemistry, physics, etc.) taken and passed WHILE ATTENDING COLLEGE, ADULT EDUCTION CLASSES, TECHNICAL OR BUSINESS SCHOOL: (21-23) (24-26)

Science Classes Taken	Passed (Yes or No)

38. Indicate your reason(s) for attending WC_3: (27-33)

1. Learning for its own sake
2. To meet people/make friends
3. To achieve a personal goal
4. To improve yourself
5. To get a promotion or raise
6. Low Cost
7. Closeness to home
8. Has the program I wanted
9. Other (please specify) ________________________________

39. Indicate your course of study or program. (34)

1. Vocational/technical/business
2. Allied health programs
3. Liberal arts leading to an associate degree
4. General Transfer program
5. Don't know
6. Other (please specify) ________________________________

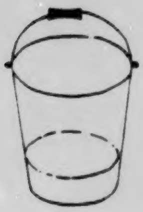
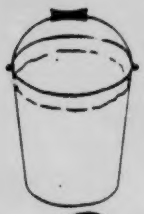
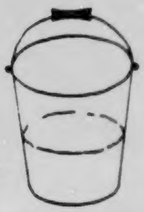
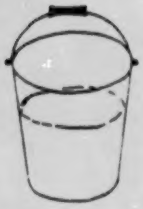
APPENDIX E

AN INVENTORY OF PIAGET'S DEVELOPMENTAL TASKS

developed by the
Center for Research
in Thinking and Language
Department of Psychology
Catholic University
Washington, D.C. 20017

example

Which pail has the most water?

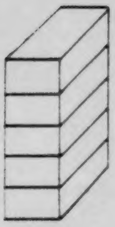
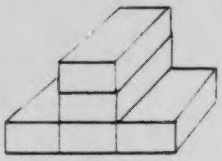
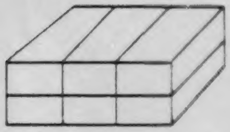
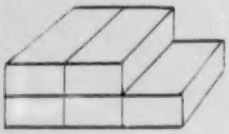
A [✓ B] C D

1

Here are some blocks.

The blocks are put into piles.

Which pile has the most blocks?

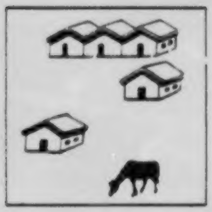





A B C D

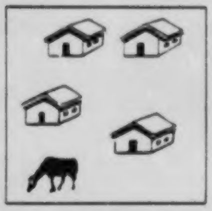
2

Here is a hungry horse.

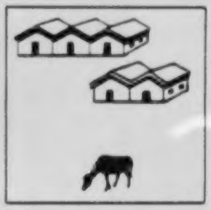
Where does the horse get the most grass to eat?



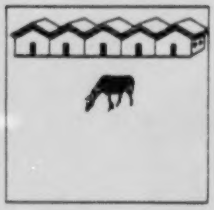
A



B



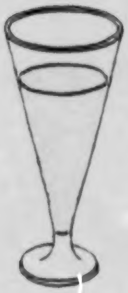
C



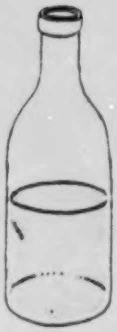
D

3

Which one has the most water?



A



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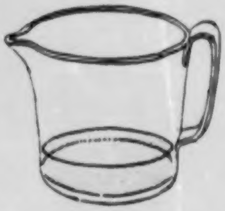
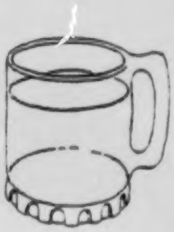


C

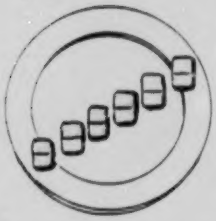


D

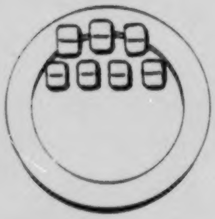
4

Here are some cookies.

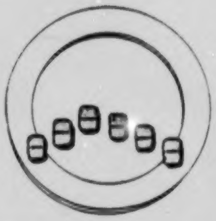
Which plate has the most cookies?



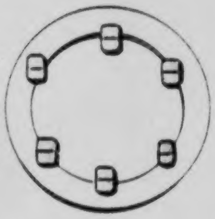
A



B



C



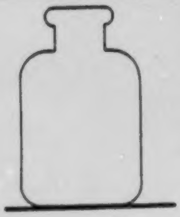
D

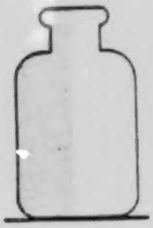
example

Here is a bottle on a table.

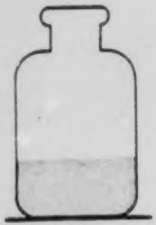
We put water in the bottle.

What does the water look like in the bottle?

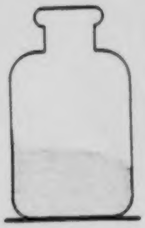




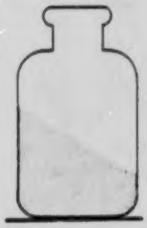
A



[✓ B]

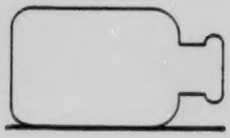


C



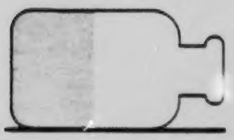
D

We turn the bottle this way.

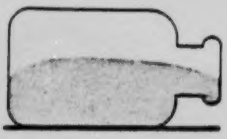


5

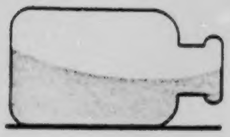
What does the water look like?



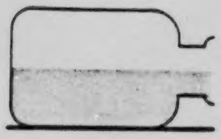
A



B

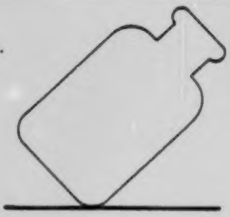


C



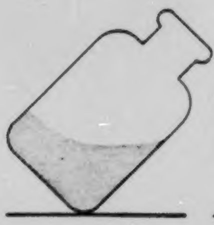
D

Now we turn the bottle this way.

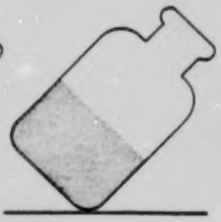


6

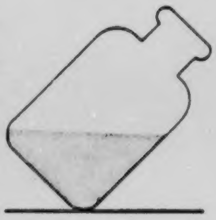
What does the water look like?



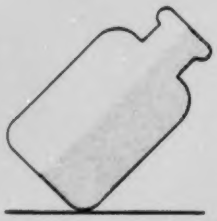
A



B



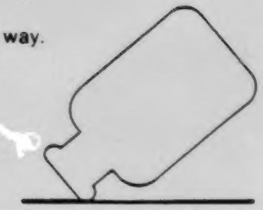
C



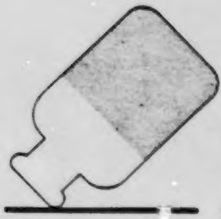
D

7

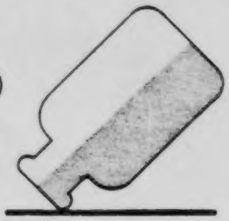
Now we turn the bottle this way.



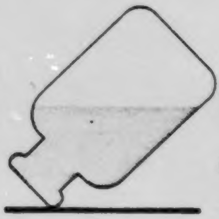
What does the water look like?



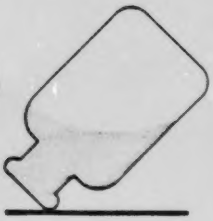
A



B



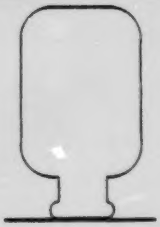
C



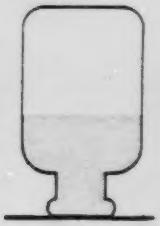
D

8

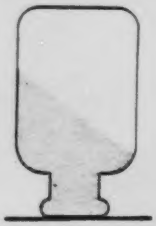
Now we turn the bottle this way.



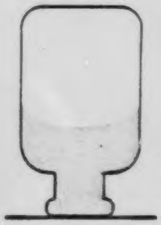
What does the water look like?



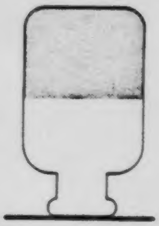
A



B

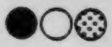
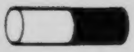


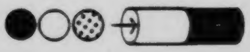
C



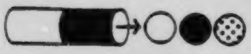
D

example

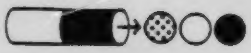
Here are 3 balls  and a tube. 

We roll the balls into the tube this way. 

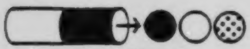
How do they come out?



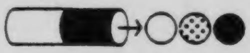
A



B

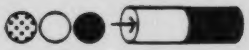


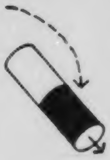
[✓ C]



D

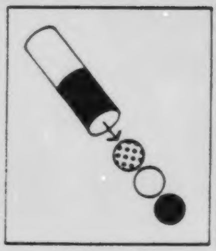
9

We put the balls into the tube this way. 

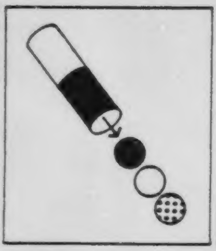


We turn the tube like this.

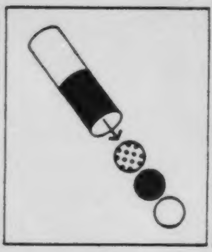
How do the balls come out?



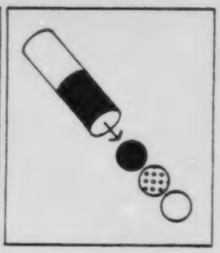
A



B



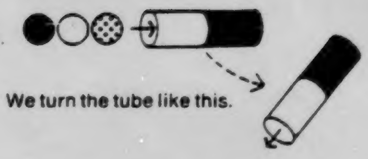
C



D

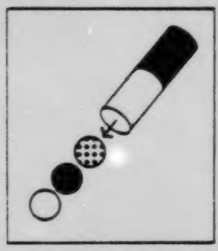
10

We put the balls into the tube this way.

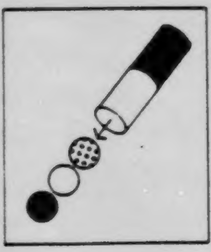


We turn the tube like this.

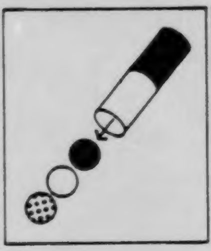
How do the balls come out?



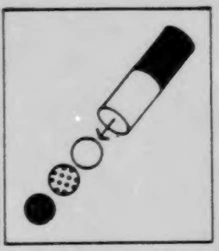
A



B



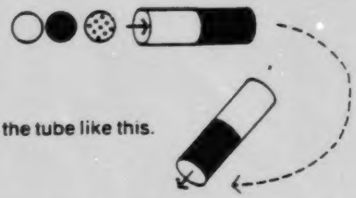
C



D

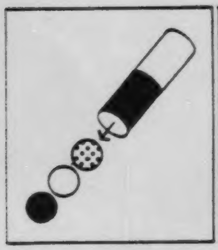
11

We put the balls into the tube this way.

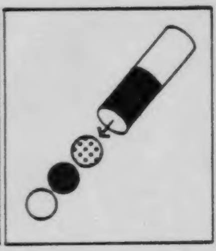


We turn the tube like this.

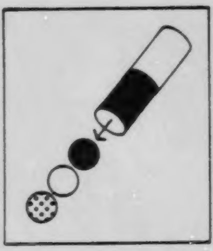
How do the balls come out?



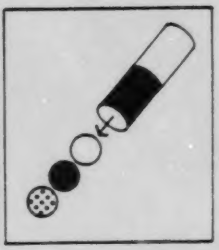
A



B



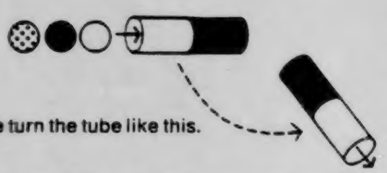
C



D

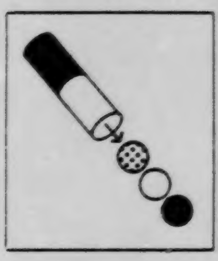
12

We put the balls into the tube this way.

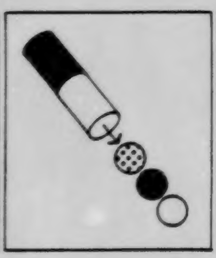


We turn the tube like this.

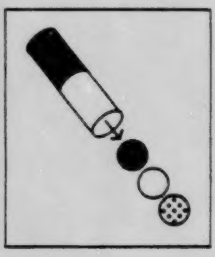
How do the balls come out?



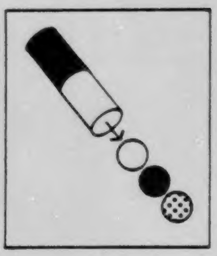
A



B



C



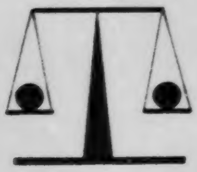
D

example

Here are two balls. ● ●

We put the balls on a balance scale.

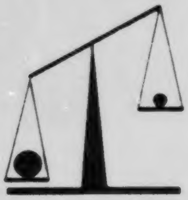
Look at the scale. The balls weigh the same.



Here are two other balls. ● •

Look at the scale

The big ball weighs more.



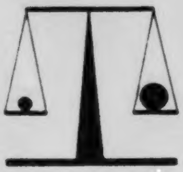
example

We have some clay.

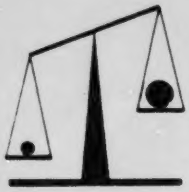
We make two balls, one big and one small. ● ●

We put the balls on the scale.

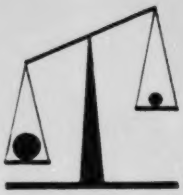
What happens?



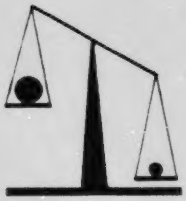
A



B



[✓ C]



D

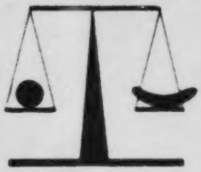
13

Here are two balls of clay. ● ●

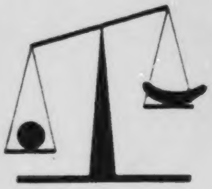
The balls weigh the same.

Now we make one ball look like a banana. ●

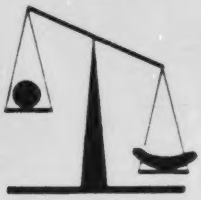
We put them on the scale. What happens?



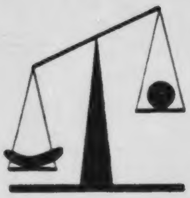
A



B



C



D

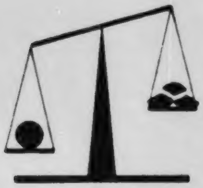
14

Here are two balls of clay. ● ●

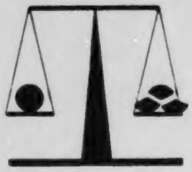
The balls weigh the same.

Now we cut one ball into 3 pieces. ●

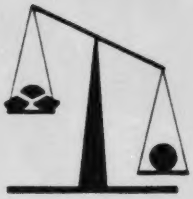
We put them on the scale. What happens?



A



B



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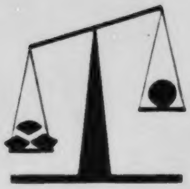


D

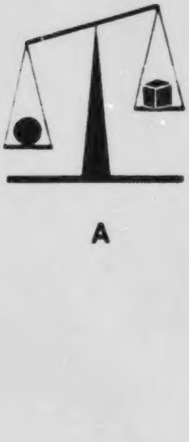
Here are two balls of clay. ● ●

15

The balls weigh the same.

Now we make one ball look like a box. ●

We put them on the scale. What happens?



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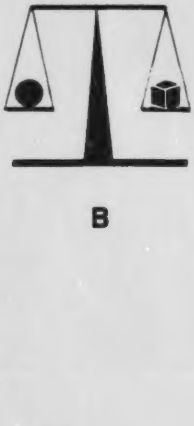

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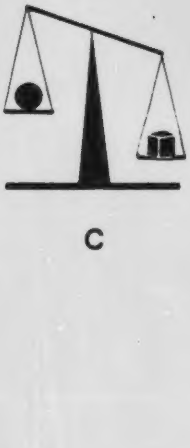

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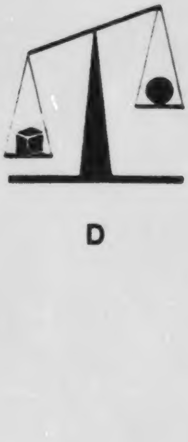


D

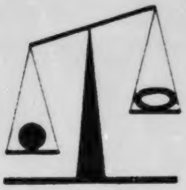
16

Here are two balls of clay. ● ●

The balls weigh the same.

Now we make one of the balls into a ring. ● ⬭

We put them on the scale. What happens?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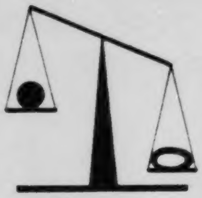
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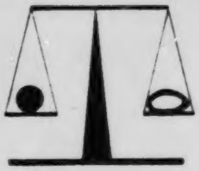
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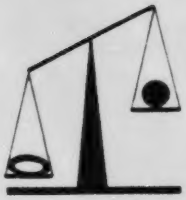
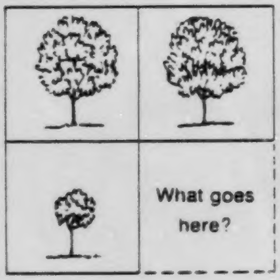
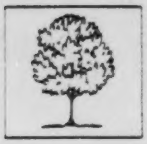

D

example


What goes here?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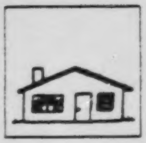
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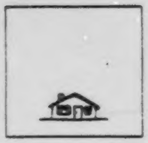
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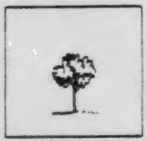
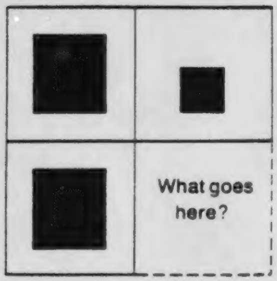

[✓ D]

17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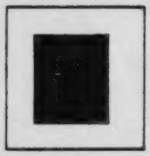
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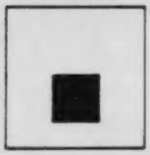
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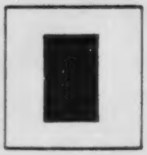
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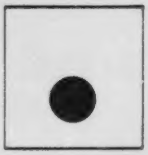
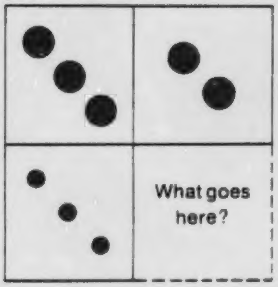
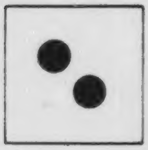

D

18


What goes here?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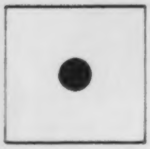
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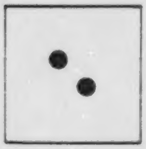
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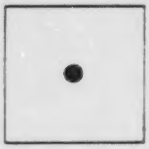
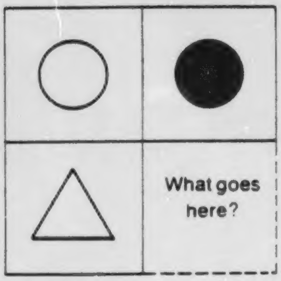

D

19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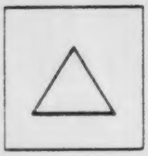
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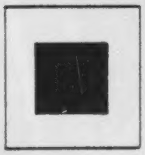
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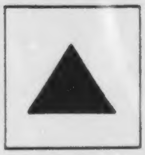
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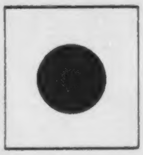
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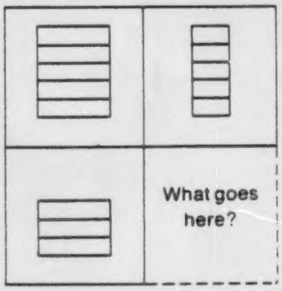
20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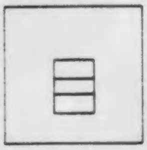
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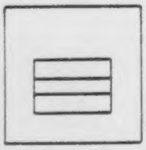
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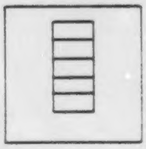
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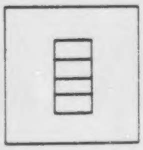
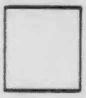
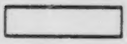
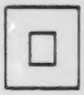

D

example

y = 

x = 

x+y = ?



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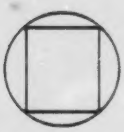

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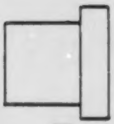
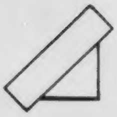
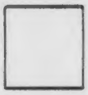


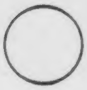
[✓ C]



D

21

x = 

y = 

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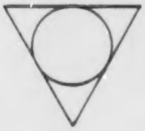

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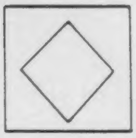

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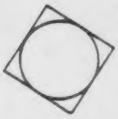

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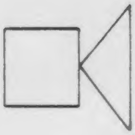
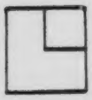


D

22

x+y =



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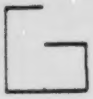

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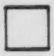

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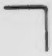

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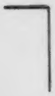

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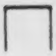
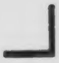


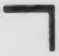
D

23

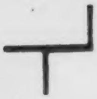
x =



y =



x+y = ?



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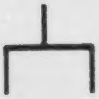

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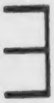

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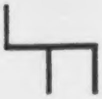


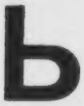
D

24

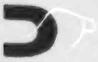
x= **I**

x+y= **B**

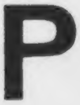
y= ?



A



B



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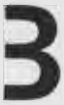

D

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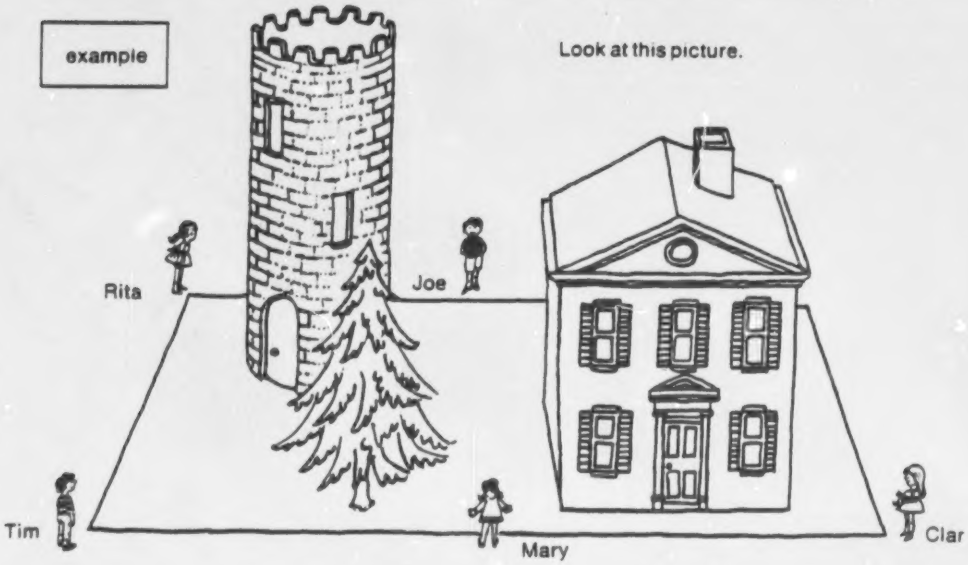
example

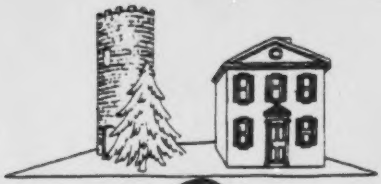
Look at this picture.


Rita
Joe
Tim
Mary
Clar

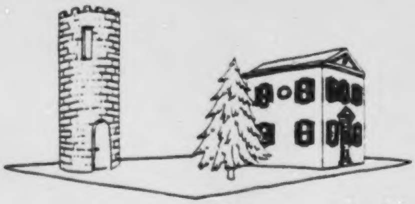
example

Look at the picture in the example on page 16.

What does Mary see?



[✓ A]



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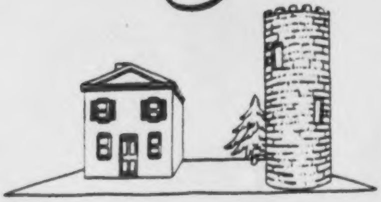

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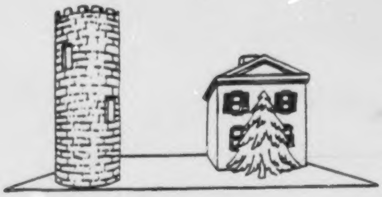
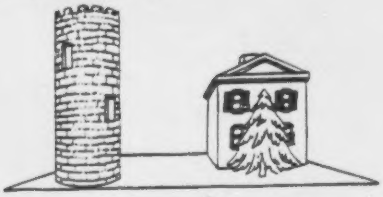


D

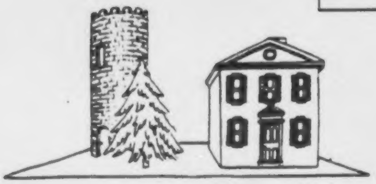
Look at the picture in the example on page 16.

What does Joe see?

25



A



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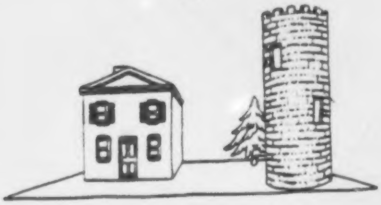
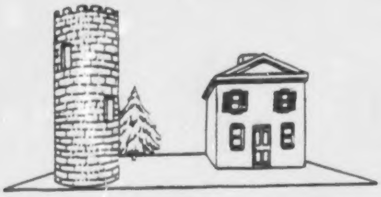


C

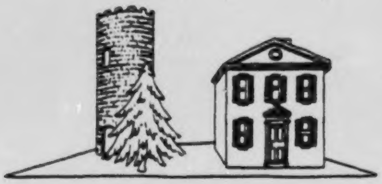


D

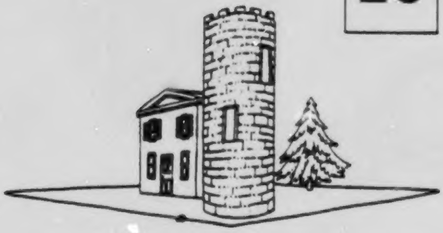
Look at the picture in the example on page 16.

What does Tim see?

26



A



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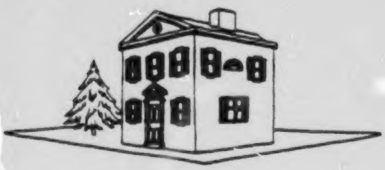

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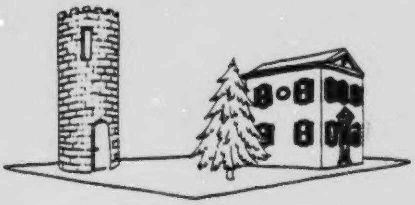
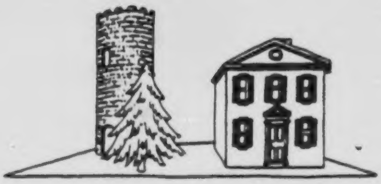


D

Look at the picture in the example on page 16.

What does Rita see?

27



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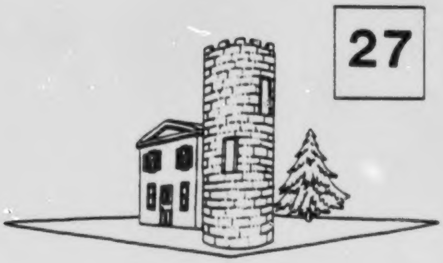

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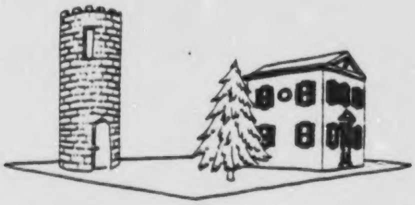

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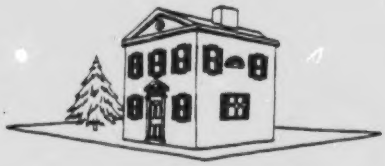
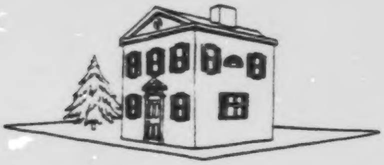


D

Look at the picture in the example on page 16.
What does Clara see?

28



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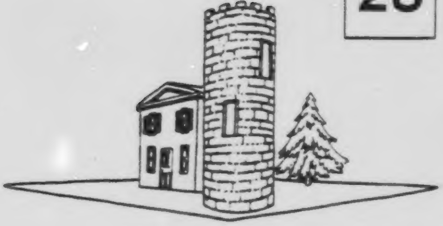

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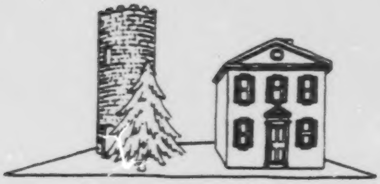

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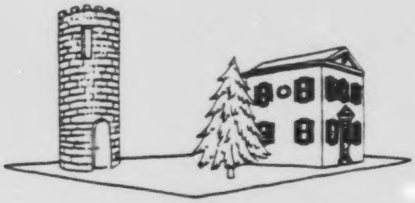

D

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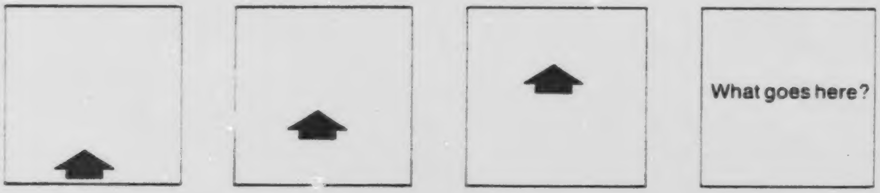
example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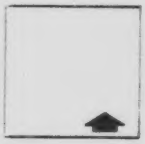

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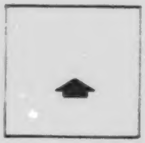

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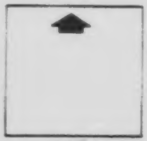
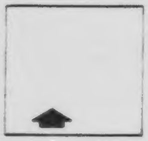
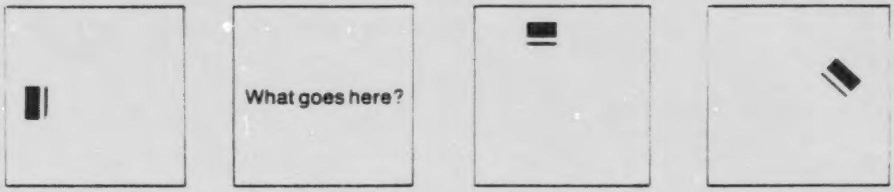


[✓ **C**]



D

29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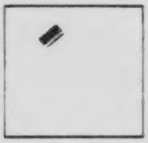
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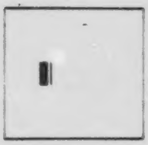
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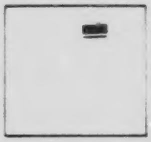
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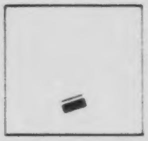
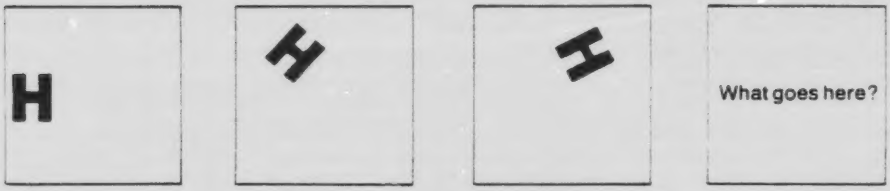

D

30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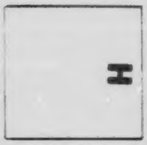
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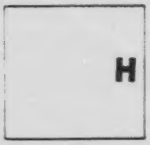
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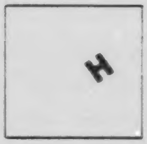
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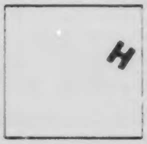
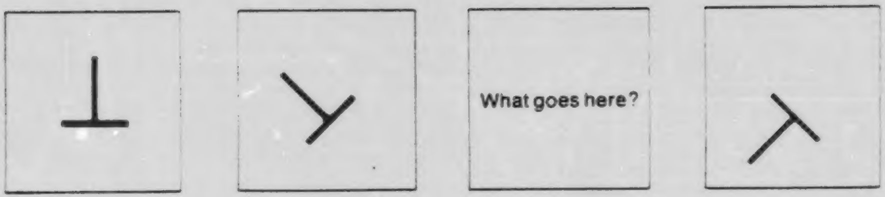

D

31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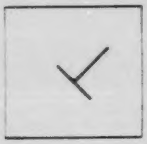
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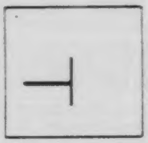
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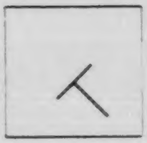
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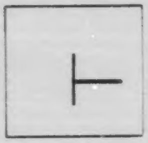
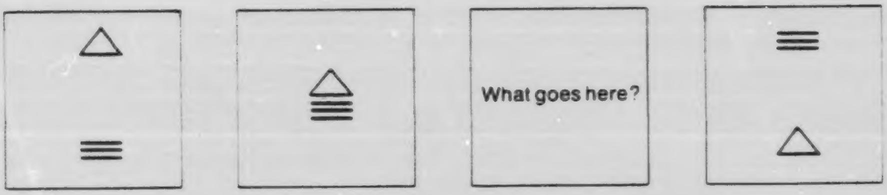
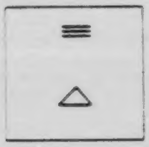

D

32


What goes here?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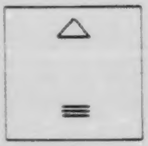
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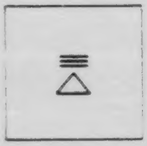
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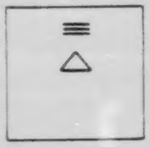
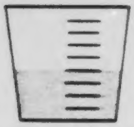
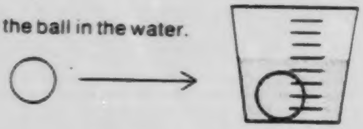

D

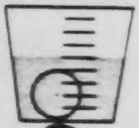
example

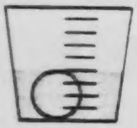
Here is a clay ball. Here is a jar of water. 

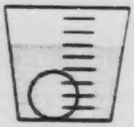
We put the ball in the water.



What happens?


[✓ A]


B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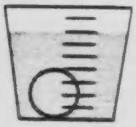
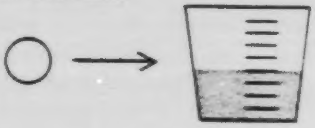
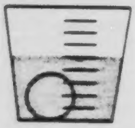

D

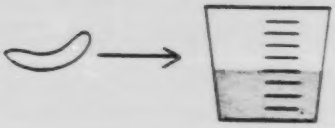
Here are two balls of clay. We make one ball look like a banana.

We put them in the water.

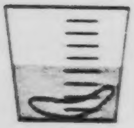


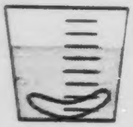


33



What happens?


A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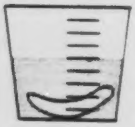
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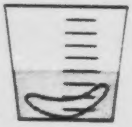
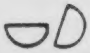
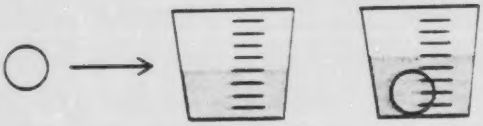
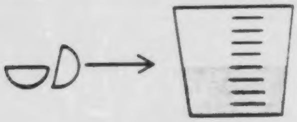

D

Here are two balls of clay. ○ ○ Now we cut one ball into 2 pieces.

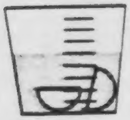


34





What happens?



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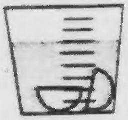
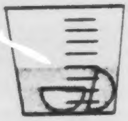
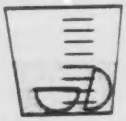


B



C

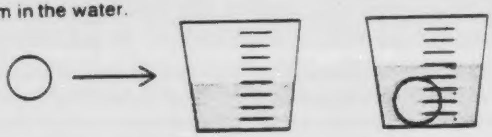


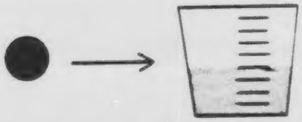
D

Here is a light ball. ○ Here is a heavy ball. ●

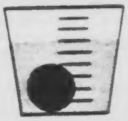
We put them in the water.

35





What happens with the heavy ball?



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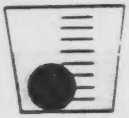

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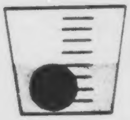

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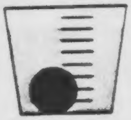
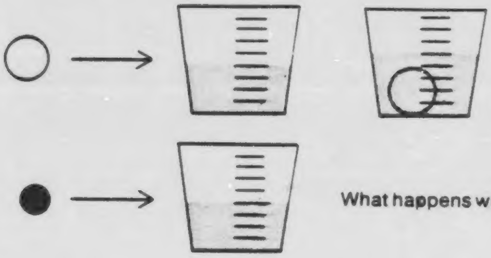


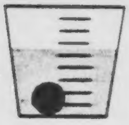
D

36

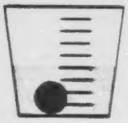
Here is a light ball. ○ Here is a small, heavy ball. ●



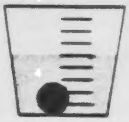
What happens with the small, heavy ball?



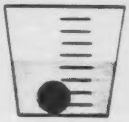
A



B



C



D

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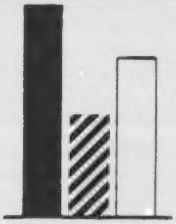
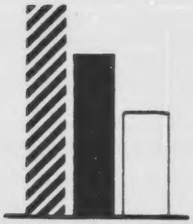
example

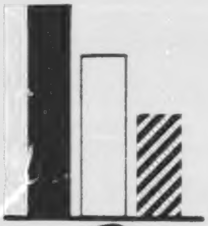
Here are 3 sticks.



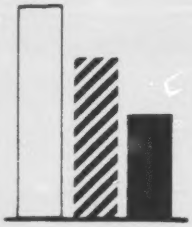
We line up the sticks from big to small. How do they look?



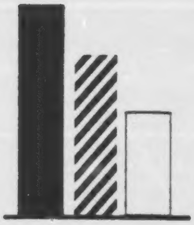
A



[✓ B]



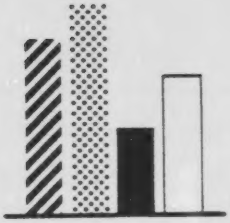
C



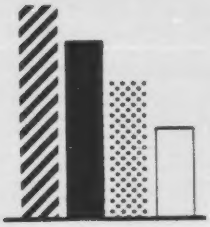
D

37

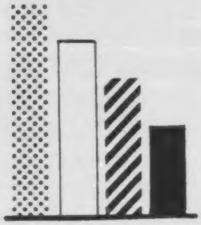
Here are 4 sticks.



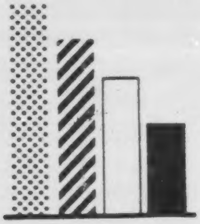
We line up the sticks from big to small. How do they look?



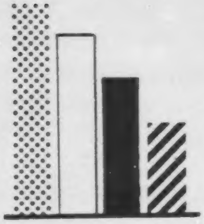
A



B



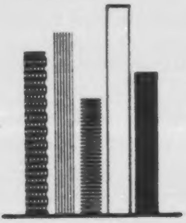
C



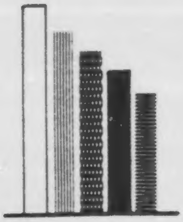
D

38

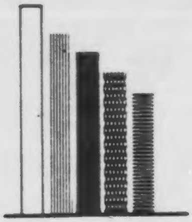
Here are 5 sticks.



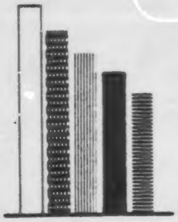
We line up the sticks from big to small. How do they look?



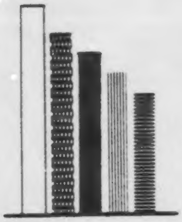
A



B



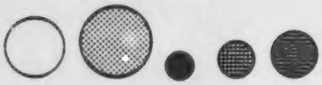
C



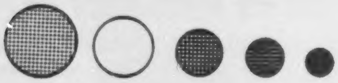
D

Here are five balls.

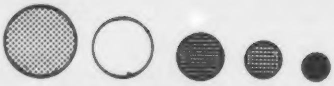
39



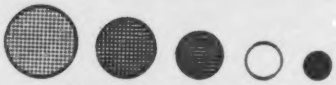
We line up the balls from big to small. How do they look?



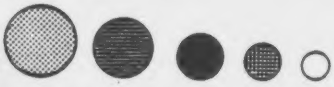
A



B



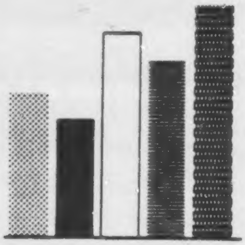
C



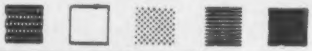
D

Here are five sticks.

40



When the sticks are lined up from big to small which is the right order?

A


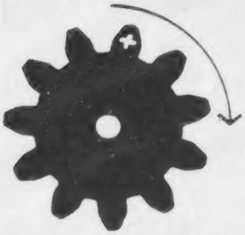
B

C

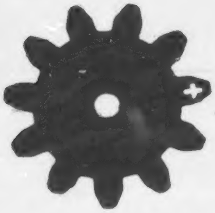
D

example

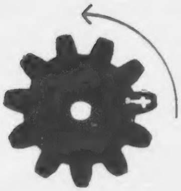
Here is a wheel.



The wheel turns down.

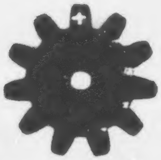


It looks like this.

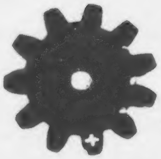


Now the wheel turns up this far.

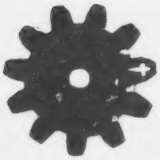
What does it look like?



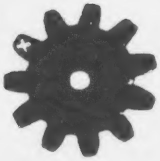
[✓ A]



B



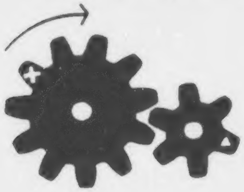
C

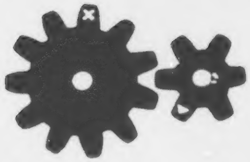


D

Here are two wheels. The big one turns up.

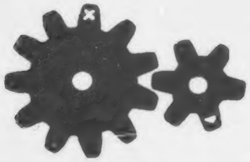
41



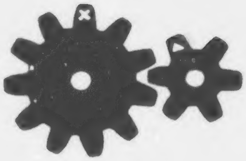


A

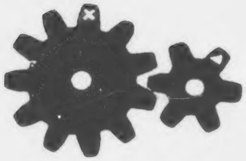
What do the wheels look like now?



B



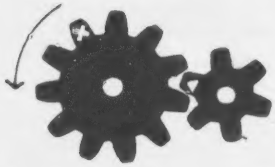
C

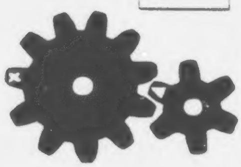


D

Here are two wheels. The big wheel turns down.

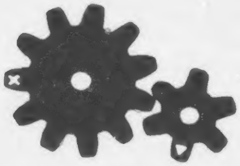
42



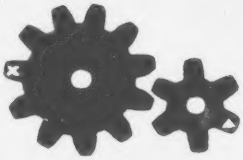


A

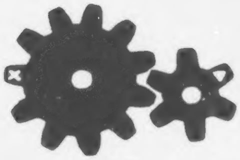
What do the wheels look like now?



B



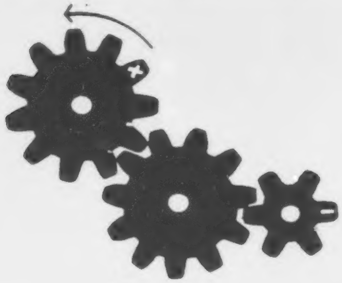
C



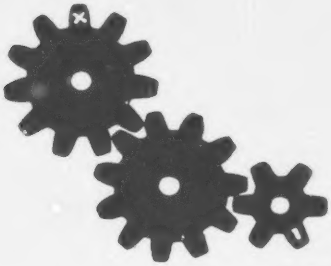
D

43

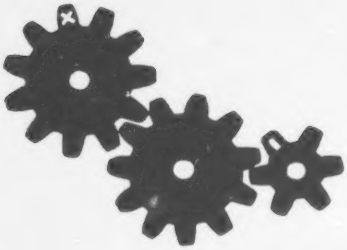
Here are three wheels. The left wheel turns up.



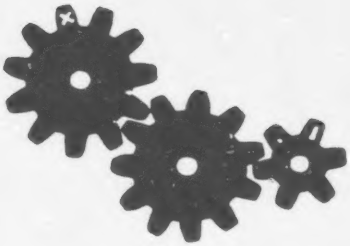
What do the wheels look like?



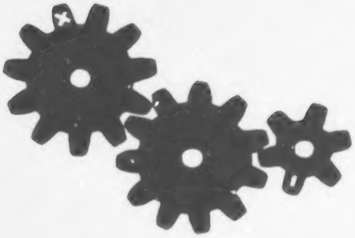
A



B



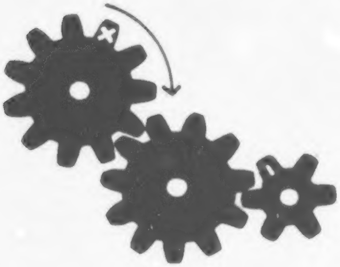
C



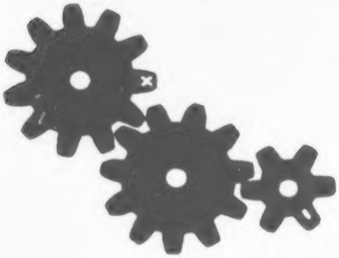
D

Here are three wheels. The left wheel turns down.

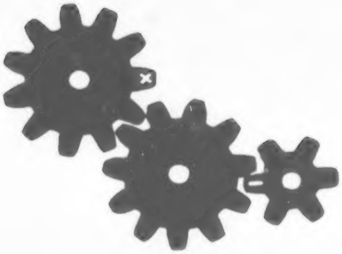
44



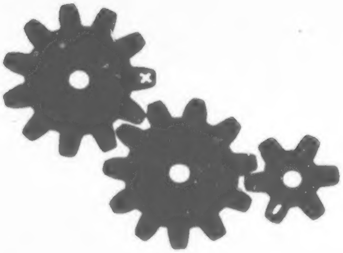
What do the wheels look like?



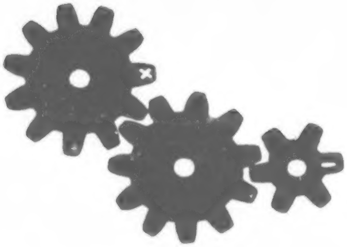
A



B



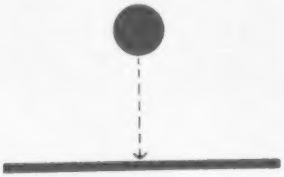
C



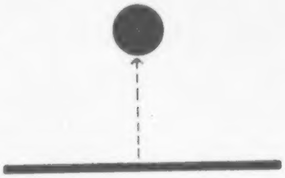
D

example

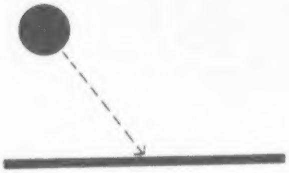
We throw the ball on the floor.



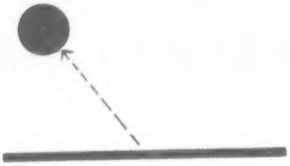
The ball bounces back.



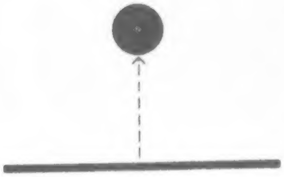
We throw the ball this way.



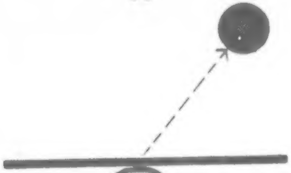
How does the ball bounce?



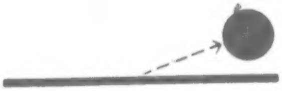
A



B



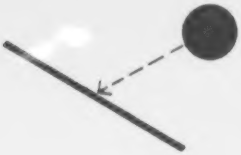
[✓ C]



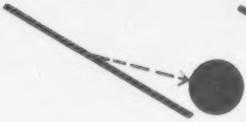
D

45

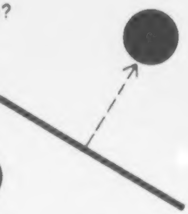
We throw the ball at a wall.



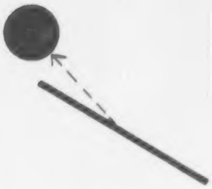
How does the ball bounce?



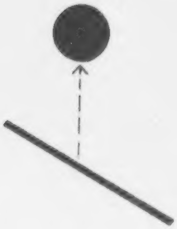
A



B



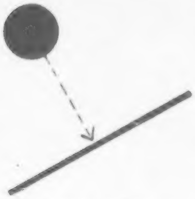
C



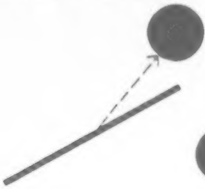
D

46

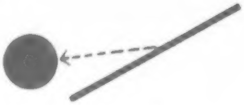
We throw the ball at a wall.



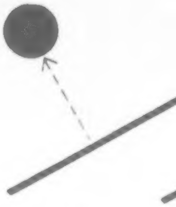
How does the ball bounce?



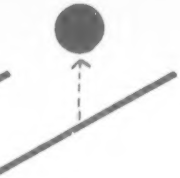
A



B



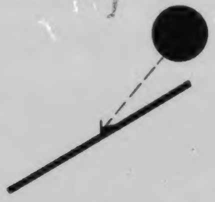
C



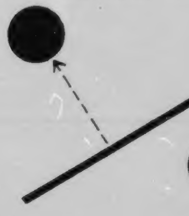
D

47

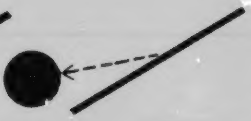
We throw the ball at a wall.



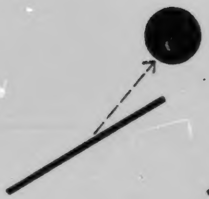
How does the ball bounce?



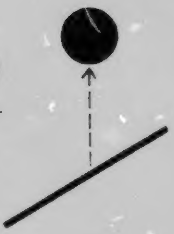
A



B



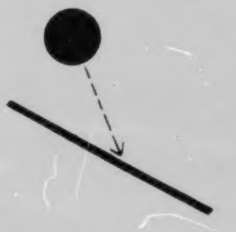
C



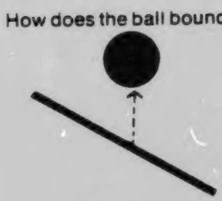
D

48

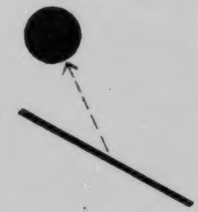
We throw the ball at a wall.



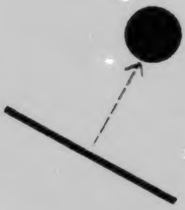
How does the ball bounce?



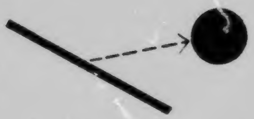
A



B

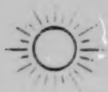


C

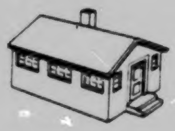


D

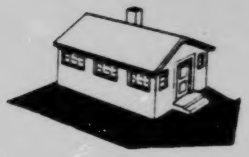
example



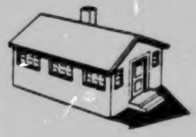
The sun is shining behind the house.



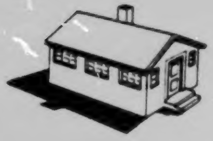
How does the shadow look?



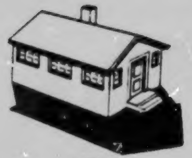
A



B

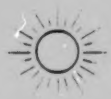


C

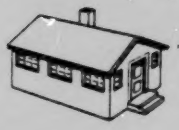


[✓ D]

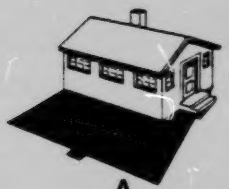
49



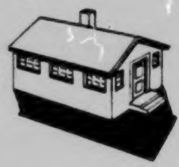
Now the sun moves here.



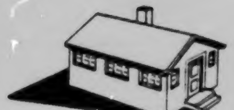
What does the shadow look like now?



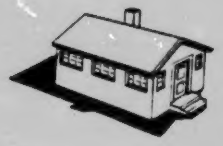
A



B

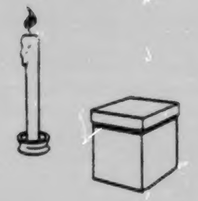


C



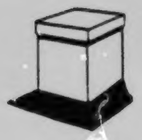
D

50

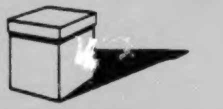


Here is a candle and a box.

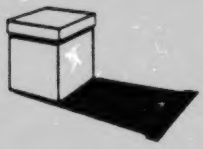
How does the shadow look?



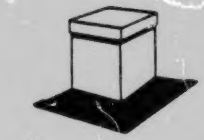
A



B



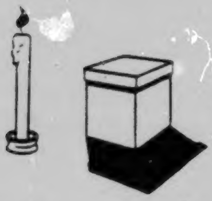
C



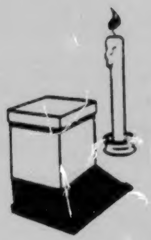
D

51

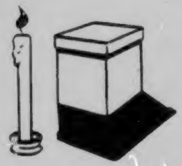
Which picture is right?



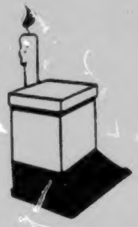
A



B



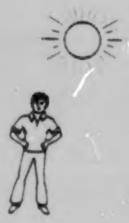
C



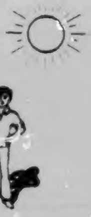
D

The sun shines on a man this way.

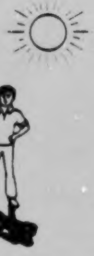
52



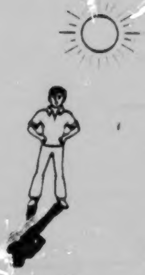
How does the shadow look?



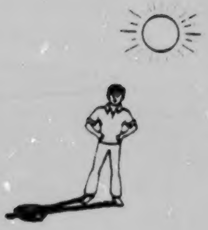
A



B



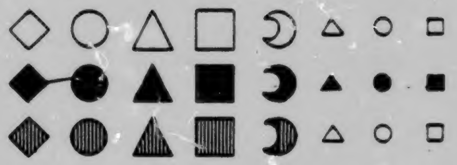
C



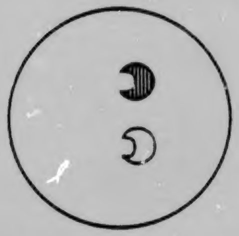
D

example

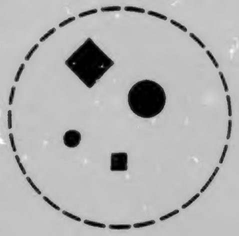
We have many different blocks like these.



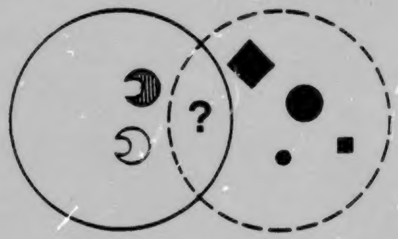
These blocks go in this circle.



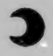
These blocks go in this circle.



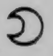
We put the circles together like this.



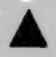
Which block belongs in the middle?



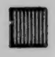
[✓ A]



B



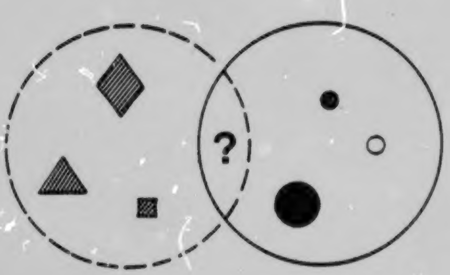
C



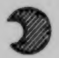
D

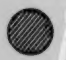
53

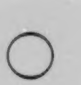
Here are two circles.



Which block belongs in the middle?


A

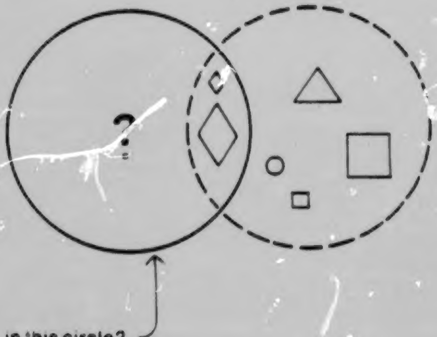

B


C

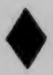
D

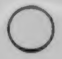
54

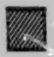
Here are two circles.



Which block belongs in this circle?


A

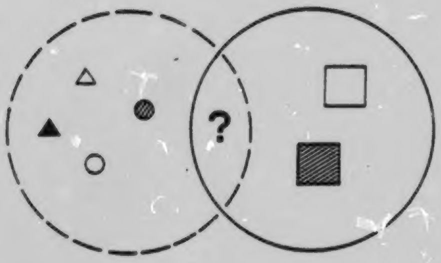

B


C

D

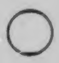
55

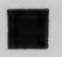
Here are two circles.



Which blocks belong in the middle?

A

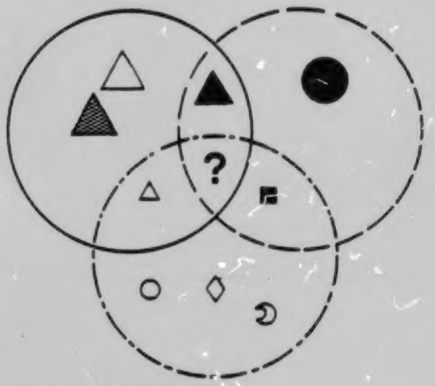

B


C

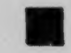
D

56

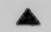
Here are three circles.



Which block belongs in the middle?


A

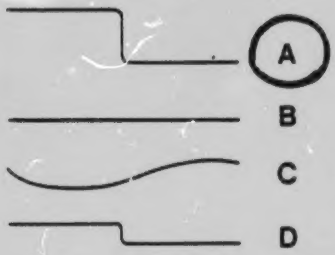
B


C

D

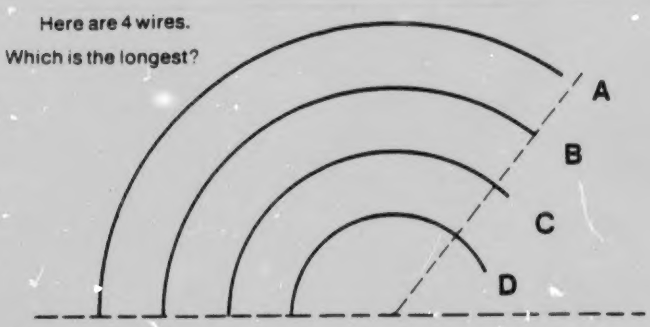
example

Here are 4 wires.
Which is the longest?



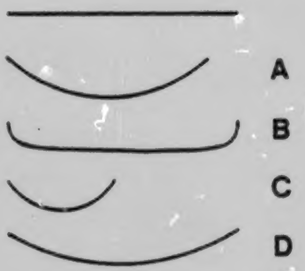
57

Here are 4 wires.
Which is the longest?



58

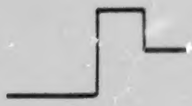
Here is a piece of wire.
We bend the wire.
What does it look like?

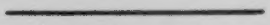


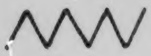
59

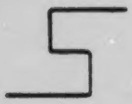
Here are 4 wires.

Which is the shortest?

A 

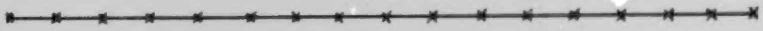
B 

C 

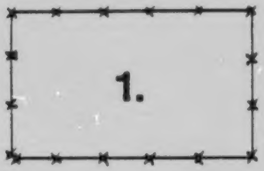
D 

60

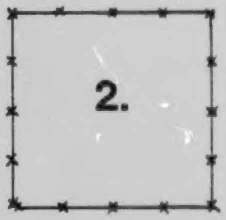
Here is a long piece of barbed wire.



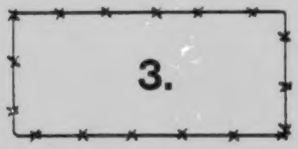
We bend it to make figure 1.



Then bend the same wire to make figure 2.



Then bend the same wire to make figure 3.



Which figure is the largest or are they all the same?

No. 1 largest
A

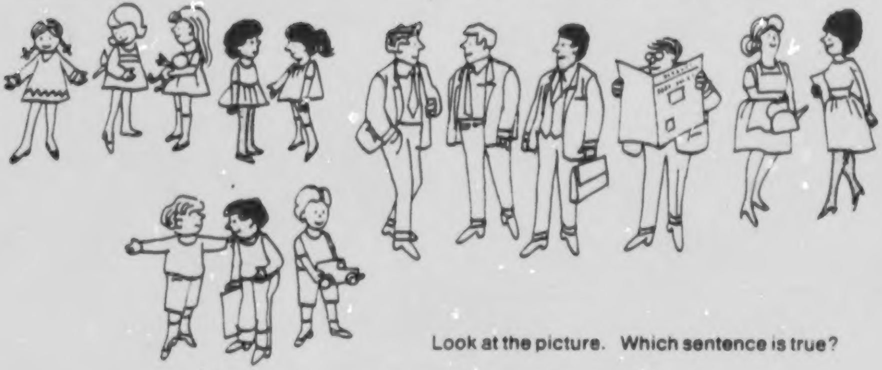
No. 2 largest
B

No. 3 largest
C

all the same
D

example

Here are many people.
There are 5 girls, 3 boys, 4 fathers and 2 mothers.



Look at the picture. Which sentence is true?

A There are more boys than girls.

B There are more adults than children.

[✓ **C**] There are more children than adults.

D There are more mothers than fathers.

Look at the picture. Which sentence is true?

61

A There are more fathers than adults.

B There are more mothers than fathers.

C There are more fathers than girls.

D There are more adults than fathers.

62

Look at the picture. Which sentence is true?

A There are more mothers than fathers.
B There are as many fathers as adult men.
C There are more fathers than adult men.
D There are more adult men than fathers.

63

Look at the picture. Which sentence is true?

A There are more boys than girls.
B There are more girls than children.
C There are as many girls as children.
D There are more children than girls.

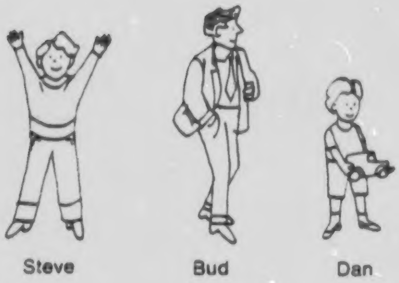
64

Look at the picture. Which sentence is true?

A There are more children than people.
B There are more people than children.
C There are as many children as people.
D There are more fathers than children.

example

Look at these three boys.



Which sentence is true?

- **A** Dan is bigger than Bud.
- [✓ **B**] Bud is bigger than Dan.
- **C** Steve is bigger than Bud.
- **D** Dan is bigger than Steve.

65

Now picture in your mind that:

Louis is bigger than Frank.
Frank is bigger than Joe.

Which sentence is true?

- **A** Joe is bigger than Frank.
- **B** Louis is bigger than Joe
- **C** Frank is bigger than Louis.
- **D** Joe is bigger than Louis.

66

Now picture in your mind that:

Henry is bigger than Victor.
John is not as big as Victor.

Which sentence is true?

- **A** John is bigger than Henry.
- **B** John is bigger than Victor.
- **C** Victor is bigger than Henry.
- **D** Henry is bigger than John.

67

Now picture in your mind that:

Don is not as big as Tom.
Bob is not as big as Don.

Which sentence is true?

- **A** Bob is bigger than Tom.
- **B** Bob is bigger than Don.
- **C** Tom is bigger than Bob.
- **D** Don is bigger than Tom.

68

Now picture in your mind that:

Jim is bigger than Al.
Al is bigger than Ron.
Dick is bigger than Jim.

Which sentence is true?

- **A** Ron is bigger than Jim.
- **B** Dick is bigger than Al.
- **C** Ron is bigger than Dick.
- **D** Al is bigger than Dick.

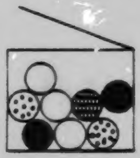
example

Here are some balls:

Some like this. ◉ Some like this. ● Some like this. ◍ Some like this. ○

Now you put 8 balls into a box.

You shake the box.



You close your eyes and take out one ball.

Which ball do you guess you will take out?

○ ● ◍ ◉

[✓ A] B C D

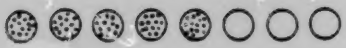
69

We put these balls into a box. ○ ◍ ◍ ◍

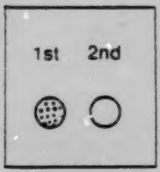
Which balls do you guess you will take out 1st and 2nd ?

	A	B	C	D
1st	○	◍	○	◍
2nd	◍	◍	○	○

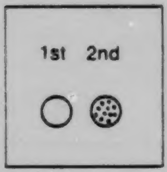
70

We put these balls into a box. 

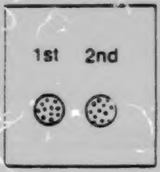
Which balls do you guess you will take out 1st and 2nd ?



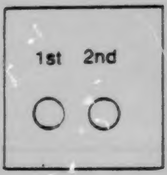
A



B

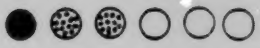


C

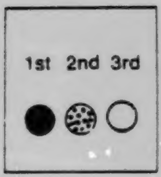


D

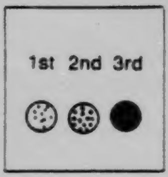
71

We put these balls into a box. 

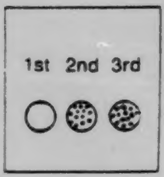
Which balls do you guess you will take out 1st, 2nd, and 3rd?



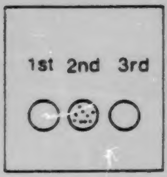
A



B



C



D

72

We put these balls into a box. ● ● ● ◍ ○ ○

Which balls do you guess you will take out 1st 2nd and 3rd?

	1st	2nd	3rd
A	●	○	●
B	●	◍	○
C	●	○	○
D	●	○	◍

APPENDIX F

STUDENT CONSENT FORM

I understand the purpose of this research project conducted by Janet M. Dettloff for her doctoral dissertation at The University of Michigan.

If I agree to participate in this project, I will complete the following forms:

1. General Biology Student Survey
2. Nelson-Denny Reading Test, Form F
3. The C.G.P. Applied Arithmetic Placement Test
4. An Inventory of Piaget s Developmental Tasks

I realize my participation in this project is completely voluntary, in whole or in part. This means that if I participate, I may choose to stop at any time on any instrument or on any question(s).

I understand that my final course grade will be used by the researcher in the data analysis.

I know the results will be confidential and coded and that the individual results will be unidentifiable when published in the dissertation.

Therefore, I agree to participate in this project.

____

Student's Signature

Janet Dettloff
Biology Instructor
Wayne County Community College

APPENDIX G

REPORT OF INDIVIDUAL SCORES

Dear WC_3 General Biology Student,

Thank you for participating in my research project. Your help and cooperation is greatly appreciated.

Although only group results will be used in the dissertation, I am pleased to provide your individual results as you requested.

Nelson-Denny Reading Test Form F:

Vocabulary Score ________

Comprehension Score ________

Reading Grade Level ________

Applied Arithmetic Placement Test:

Number Correct ________

These scores reflect your reading and math skills on the day the tests were administered. Should you feel either or both of these areas may be a problem, there are services available at the Institute for Human Resources to help you improve these skills.

Inventory of Piaget's Developmental Tasks:

Skill (the skill is underlined)	Have Skill	Do Not Have Skill
1. Ability to determine quantity		
2. Ability to determine proper levels of water		
3. Ability to determine sequence of balls in a tube		
4. Ability to determine weight/mass of clay balls		

Skill (the skill is underlined)	Have Skill	Do Not Have Skill
5. Ability to determine matrix by selecting the proper figure to match the other figures		
6. Ability to determine symbols x + y = ?		
7. Ability to determine perspective by observing the house from different viewpoints		
8. Ability to determine movement by selecting the appropriate figure to fit the movement of the other figures		
9. Ability to conserve volume by observing the level of water when various clay balls were dropped into the water		
10. Ability to arrange objects in a series		
11. Ability to perform rotation by determining how gears rotate		
12. Ability to determine angles using balls bounced off a flat surface		
13. Ability to determine shadows produced by various directions of sun and candles		
14. Ability to classify objects by selecting the correct figure to fit in the circles		
15. Ability to determine length/distance using wires bent into various shapes		
16. Ability to include using adults, children, boys, and girls		

Skill (the skill in underlined)	Have Skill	Do Not Have Skill
17. Ability to infer by determining who was larger		
17. Ability to do probability problems by determining the order of balls removed from a box		

It is not expected that everyone will answer all the questions correctly. You probably did best in those areas where you have past experiences. Therefore, the more kinds of experiences you have, the more likely you will have mastered various skills.

Many of these skills are taught in science and math classes. You may decide to take additional science and math classes to improve your skills.

Sincerely,

Janet Dettloff

APPENDIX H

TABLE OF DEMOGRAPHIC DATA

Variable	Category	N	%
Graduate High School	Yes	351	84
	No	69	16
Time from Leaving High School to Starting College	<1 year	176	42
	1 - 5 years	75	18
	6 - 10 years	60	14
	11 - 15 years	48	11
	>15 years	57	14
		416	99
Total Years Attended College	0 years	275	65
	1 year	39	9
	2 years	52	12
	3 - 5 years	61	14
		420	100
Number of Credit Hours	4	8	2
	5 - 8	88	21
	9 - 11	86	21
	12 - 17	231	55
	>17	7	2
		420	100

Variable	Category	N	%
Employed	Yes	218	52
	No	201	48
		419	100
Hours Worked Per Week	0	202	48
	1 - 10	9	2
	11 - 20	40	10
	21 - 30	46	11
	31 - 40	90	21
	>40	33	8
		420	100
Occupation	Professional	11	3
	Manager	8	2
	Sales	7	2
	Clerical	44	11
	Service	113	27
	Laborer	30	7
	Homemaker	199	47
		412	99

Variable	Category	N	%
Reasons for Attending WC_3	Program	126(420)	30(100)
	Learning for Own Sake	72	17
	Meet People (Friends)	37	9
	Achieve Personal Goal	294	70
	Improve Self	208	50
	Promotion/Raise	35	8
	Low Cost	101	24
	Closeness to Home	129	31
Courses of Study or Program	Vocational/Technical or Business	42	10
	Allied Health	230	55
	Liberal Arts	67	16
	General Transfer	54	13
	Don't Know	27	6
		420	100
Science Classes Passed in High School	Physical Science	118(420)	28(100)
	General Science	225	54
	Earth Science	84	20
	Biology	301	72
	Chemistry	131	32
	Physics	54	13

Variable	Category	N	%
Math Classes Passed in High School	Refresher Math	157(420)	37(100)
	Basic Math	272	65
	Business Math	112	27
	Bookkeeping	104	25
	Pre-Algebra	166	40
	First Year Algebra	235	56
	Second Year Algebra	128	31
	First Year Geometry	140	33
	Second Year Geometry	56	13
	Trigonometry	49	12
	Pre-Calculus	18	4
	Calculus	8	2
	Computer Math	16	4
Science Courses Passed in College	Hygiene	13(420)	3(100)
	First Aid	8	2
	Chemistry	34	8
	Physical Science	19	5
Math Courses Passed in College	Basic Arithmetic	75(420)	18(100)
	Elementary Algebra	40	10
	Intermediate Algebra	18	4
	College Algebra	20	5
	Plane Geometry	6	1

Variable	Category	N	%
Financial Resources	Parents	74	18
	Job	151	36
	Mate	45	11
	Student Loan	5	1
	GI Bill	7	2
	BEOG/Pell Grant	93	22
	Scholarship	10	2
	Other Government Sources	25	6
		410	98
Children	Yes	220	52
	No	196	47
		416	99
Total Family Income	0 - 4,999	63	15
	5 - 9,999	70	17
	10 - 14,999	102	24
	15 - 19,999	50	12
	>20,000	135	32
		420	100

APPENDIX I

SUMMARY OF THE 72 ITEM IPDT

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
1	370	88	49	12	--	--
2	111	26	309	74	--	--
3	319	76	101	24	--	--
4	398	95	21	5	--	--
5	378	90	41	10	--	--
6	374	89	45	11	--	--
7	347	83	72	17	--	--
8	390	93	29	7	--	--
9	352	84	67	16	--	--
10	353	84	66	16	--	--
11	321	76	98	24	--	--
12	343	82	76	18	--	--
13	371	88	48	11	--	--
14	381	91	38	9	--	--
15	383	91	36	9	--	--
16	361	86	58	14	--	--
17	381	91	38	9	--	--
18	368	88	51	12	--	--
19	366	87	53	13	--	--
20	345	87	54	13	--	--
21	402	96	17	4	--	--

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
22	225	54	194	46	--	--
23	333	79	85	20	2	1
24	383	91	34	8	3	1
25	229	54	188	45	3	1
26	248	59	170	41	2	1
27	262	62	155	37	3	1
28	338	81	79	19	3	1
29	297	71	120	29	3	1
30	166	40	252	60	2	1
31	260	62	156	37	4	1
32	365	87	53	13	--	--
33	300	71	119	28	--	--
34	329	78	88	21	3	1
35	182	43	237	56	--	--
36	128	31	289	69	3	1
37	386	92	33	9	--	--
38	385	92	33	8	2	1
39	381	91	37	9	2	1
40	372	89	44	11	4	1
41	153	36	264	63	3	1
42	179	43	238	57	3	1

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
43	226	54	192	46	2	1
44	228	54	187	44	5	1
45	134	32	280	67	6	1
46	269	64	145	35	6	1
47	279	66	136	32	5	1
48	250	60	164	39	6	1
49	179	43	237	57	4	1
50	291	69	125	30	4	1
51	275	66	132	31	13	3
52	302	72	108	26	10	2
53	156	37	245	58	19	5
54	175	42	224	53	21	5
55	98	23	298	71	24	6
56	106	25	290	69	24	6
57	380	91	26	6	14	3
58	259	62	147	35	14	3
59	230	55	175	42	15	4
60	46	11	356	85	18	4
61	273	65	133	32	14	3
62	350	83	55	13	15	4
63	309	74	96	23	15	4

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
64	239	57	164	39	17	4
65	344	82	58	14	18	4
66	340	81	61	15	19	4
67	319	76	79	19	22	5
68	282	67	115	27	23	6
69	271	65	120	29	29	7
70	257	61	134	32	29	7
71	226	54	162	39	32	8
72	231	55	153	36	36	9

$\overline{X}$ = 49.   S.D. = 10.49.

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ABSTRACT

PREDICTING ACHIEVEMENT IN COMMUNITY COLLEGE SCIENCE STUDENTS

by

Janet May Dettloff

Chairman: Burton E. Voss

This research study was designed to formulate a predictive equation which could be utilized to identify those students who most probably would not succeed in science education. Data were collected from 420 students enrolled in the General Biology Course at a largely urban mid-western community college which serves a heterogeneous population. The data included background characteristics, reading ability, math ability, and cognitive development level. The instruments used to collect these data were: (1) College Biology Student Survey, (2) The Nelson Denny Reading Test, Form F, (3) The CGP Applied Arithmetic Test, and (4) An Inventory of Piaget's Developmental Tasks.

The data showed that the General Biology classes had a higher percentage of females (82%) than males (18%). The students' median age was 26. The classes were racially balanced (49% white, 51% non-white). The majority of the students (71%) were single or formerly married. The

students' average math score was 15 correct answers out of 25 choices on a math test approximately sixth grade level. The students' average reading ability was the twelfth grade level. Only 9% of the students were at the formal level of cognitive development. The average grade was 2.7 (C+).

Multiple regression was used for the analyses. Background characteristics, reading and math ability accounted for 42% of the variance in the students' cognitive development and 43% of the variance in the students' achievement. Cognitive development accounted for 12.8% of the variance in the students' achievement. With cognitive development as a mediating variable, the background characteristics, reading and math ability accounted for 22% of the variance in the students' achievement. The predictive equation formulated was:

$$Y' = 0.42 + 0.14 \text{ cognitive development} + 0.18 \text{ reading ability} + 0.13 \text{ math ability} + 0.04 \text{ race} + 0.04 \text{ mothers' occupation} + 0.07 \text{ fathers' education} + -0.11 \text{ number of siblings} + -0.06 \text{ marital status.}$$

Recommendations were made about the improvement of these students in the basic skills area.

PREDICTING ACHIEVEMENT IN COMMUNITY COLLEGE SCIENCE STUDENTS

by

Janet May Dettloff

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Education)
in The University of Michigan
1982

Doctoral Committee:

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Professor Charles F. Lehmann
Associate Professor Charles F. Yocum

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To My Family

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TABLE OF CONTENTS

DEDICATION ii

ACKNOWLEDGMENTS iii

LIST OF TABLES viii

LIST OF FIGURES x

LIST OF APPENDICES xi

CHAPTER

I. INTRODUCTION 1

Background and Need for the Study 3
Purpose and Plan of the Study 6
Rationale for Selecting the Variables . . . 10
Research Hypotheses 11
Assumptions of This Study 13
Limitations of the Study 13
Significance of the Study 13
Summary 14

II. REVIEW OF THE RELATED LITERATURE 15

Introduction 15
The Relationship of Background Characteristics to Achievement in Community College Students 15
The Relationship of Background Characteristics to Achievement in Science Education 17
Piagetian Cognitive Development 18
Relationship of Background Characteristics to Cognitive Development 21
The Relationship Between Reading and Math Ability and Cognitive Development 23
The Relationship of Reading and Math Ability to Achievement in Community College Students 26

The Relationship of Reading and Math Ability to Achievement in Science Education 26
Relationship of Cognitive Development to Achievement in Science Education 27
Summary of the Research 29

III. RESEARCH PROCEDURES 30

Selection and Description of the Sample . . 30
Description of the Test Measures 31
Description of Achievement in Science Education 39
Data Collection 40

IV. ANALYSIS OF DATA 43

Description of the Variables 45
Analysis of the Data 61
Analyses of Background Characteristics . . 63
  Research Hypothesis One 63
  Research Hypothesis Two 79
Analyses of Reading and Math Ability . . . 85
  Research Hypothesis Three 85
  Research Hypothesis Four 88
Analysis of Cognitive Ability and Achievement in Science Education 90
  Research Hypothesis Five 90
Analysis in Background Characteristics, Cognitive Development and Achievement in Science Education 93
  Research Hypothesis Six 93
Analysis of Reading and Math Ability, Cognitive Development and Achievement in Science Education 93
  Research Hypothesis Seven 93
Analysis of All Variables and Achievement in Science Education 95
  Research Hypothesis Eight 95
Analysis of Cognitive Development as an Intervening Variable 96
  Research Hypothesis Nine 96
Summary 107

V. SUMMARY, CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS 109

Summary 109
Data Analysis 110
Conclusions 119
Discussion 122
Achievement 126
Recommendations 127

APPENDICES 130

REFERENCES 205

LIST OF TABLES

Table 1. Summary of the IPDT 34

Table 2. Problem Area Skills 35

Table 3. Summary of Demographic Data 46

Table 4. Summary of Reading and Math Ability . . . 51

Table 5. Summary of 18 IPDT Tasks 52

Table 6. Summary of Five IPDT Problem Area Skills 55

Table 7. Summary of Grades 60

Table 8. Summary Statistics of the Individual Background Characteristics as Related to Total Score on the IPDT 72

Table 9. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Relations . . 73

Table 10. Summary Statistics of the Individual Background Characteristics as Related to the Probelm Area Skill, Imagery . . . 74

Table 11. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Conservation 75

Table 12. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Classification 76

Table 13. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Proportional Reasoning 77

Table 14. Summary Statistics of the Combined Background Characteristics as Related to Total Score on the IPDT and the Five Problem Area Skills 80

Table 15. Summary Statistics of the Individual Background Characteristics as Related to Achievement in Science Education . . . 83

Table 16. Summary Statistics of the Combined Background Characteristics as Related to Achievement in Science Education . . . 84

Table 17. Summary Statistics of the Reading and Math Ability as Related to Total Score and the Five Problem Area Skills 89

Table 18. Summary Statistics of the Reading and Math Ability as Related to Achievement in Science Education 91

Table 19. Summary Statistics of Cognitive Development as Related to Achievement in Science Education 92

Table 20. Summary of the Multivariate Statistics of the Combined Background Characteristics, Reading and Math Ability and Cognitive Development as Related to Achievement in Science Education 94

Table 21. Path Analysis Residuals 100

Table 22. Partial Betas of Achievement in Science Eduction 104

Table 23. Correlation Matrix 106

243

LIST OF FIGURES

Figure 1. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability and Cognitive Development 8

Figure 2. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability Achievement in Science Education 8

Figure 3. Simple Paradigm Showing Relationships of Variables 9

Figure 4. Paradigm 98

Figure 5. Path Analysis Paradigm 102

LIST OF APPENDICES

Appendix A. Request for Permission for Research Study 131

Appendix B. Approval of Research Study 132

Appendix C. Random Selection Procedures 133

Appendix D. The College Biology Student Survey . . . 134

Appendix E. An Inventory of Piaget's Developmental Tasks 143

Appendix F. Student Consent Form 192

Appendix G. Report of Individual Scores 193

Appendix H. Table of Demographic Data 196

Appendix I. Summary of the 72 Item IPDT 201

CHAPTER I

INTRODUCTION

The community college is an institution whose goal is to facilitate the entry and education of persons who do not fit the traditional college model: students having prior marginal academic performances and students 22-60+, having academic ability but having delayed their entrance to higher education (Cohen, 1982). To accomplish this goal an open-door policy is advocated.

> "The Carnegie Commission supports open access to the 'open-door' college for all high school graduates and otherwise qualified individuals. The community colleges have a particular role to play in assuring equality of opportunity to all Americans (Carnegie Commission on Higher Education, 1970:2)."

In addition, the community college accomplishes its goal of attracting non-traditional students by establishing schools that are readily accessible to the community.

> "More than any other single factor, access depends on proximity ... the advent of the community college as a neighborhood institution did more to open higher education to broader segments of the population than did its policy of accepting those students who had not done well in high school (Cohen, 1982:11)."

Cohen summarizes the goal of community colleges for the non-traditional students:

> "The community colleges reached out to attract those who were not being served by traditional higher education, who could not afford the tuition, who could not take the time to attend college on a full-time basis, whose ethnic background had constrained them from participating, who had inadequate preparation in the lower schools, whose educational progress had been interrupted by some temporary condition, who had become obsolete in their jobs or who had never been trained to work at any jobs, who needed a connection to obtain a job (Cohen, 1982:21)."

The concept of a two-year college which would replace the first two years of a college or university was proposed by Henry Tappan, President of The University of Michigan in 1851. This idea was periodically reiterated throughout the next century, but the concept was neither accepted nor implemented. The 1947 President's Commission on Higher Education promoted the idea that an additional two years of formal schooling beyond the high school could benefit at least half of the population.

The need for trained industrial workers, the drive for social equality and the need for continual custodial care of extended adolescents became the primary social forces which contributed to the dramatic expansion of community colleges from eight schools in 1900 to over twelve hundred in 1981 (Cohen, 1982). Career education and vocational/technical education as well as the first two years of a liberal arts education are now important facets of a community college.

Four million students enrolled in community colleges in 1980 in contrast to only one-half million in 1960. Students 25 or older have shown the highest increase (Chronicle of Higher Education, May, 1981). "The increase in enrollments was accompanied by a major change in the composition of the student body ... the (community) colleges were opened to ethnic minorities, to lower income groups and to those whose prior academic performance had been marginal (Cohen, 1981)."

Background and Need for the Study.

An example of such a community college is Wayne County Community College (WC_3) which serves as the setting for this research study.

WC_3 was founded in 1967 as mandated by the Michigan State Legislature. Located in Michigan's largest and most highly industralized area, Wayne County, WC_3's occupational/vocational/career programs are a major commitment to its student population. In addition, WC_3 offers the traditional liberal arts college transfer programs. In 1976, WC_3 became a fully accredited member in the North Central Association of Colleges and Schools.

"WC_3 is designed to provide high quality, low cost education to all within the community who need and want it and to offer this opportunity with minimal restrictions (WC_3 Catalog)." WC_3 has an open-door admission policy.

This means that for any student interested in a general studies program admission is automatic if the student is 18 or older. There are no entrance requirements nor admission tests.

WC_3 is a large urban institution with five regional centers/campuses which serve the whole of Wayne County. Each of its five regional centers/campuses provides full liberal arts and career programs as well as supporting student services facilities. The students range from the white/non-white, affluent, middle class to the poor, white/non-white, inner-city lower class. WC_3 students are a diverse group of students: day and evening, younger and older, full and part-time, frequently employed, sometimes returning to college after a prolonged hiatus. All are seeking higher education for myriad reasons. The majority of the students at WC_3 are the non-traditional adult learners. With its open-door policy and its five regional campuses, WC_3 encourages these non-traditional students to return to school.

In the Fall Semester, 1981, 21,109 students were enrolled at WC_3 making WC_3 the largest community college in Michigan. Sixty-three percent of its students are women. Over 50% of its student population is black, 44% is white, the remainder are a mixture of other racial and ethnic backgrounds. Nearly half of the students are married.

WC_3's enrollment reflects the concept of the non-traditional student body reported by Cross and Cohen.

Because WC_3 has an open-door policy, instructors are concerned with the diverse background experiences and scholastic abilities of the students entering their courses The Biology instructors have been concerned with this problem, particularly in regard to the General Biology course. This is a one-semester course which students take for many reasons: as the basic, pre-requisite course for all advanced biology courses, as a requirement for a variety of programs and also as a degree requirement for those students seeking an Associate of Arts degree. Classes with this heterogeneous student population present problems for the instructors. The instructors strive to provide for the individual differences of students and, in particular, those students who have had a high failure rate. By identifying students prone to failure before they take the General Biology course, the self-fulfilling prophecy of failure can be circumvented. Thus, the identification of the students' background characteristics and their relationship to achievement in science education became the primary focus of this study. Findings of the study would be helpful to students and instructors in attempting to meet the individual needs of both.

Purpose and Plan of the Study.

The major purpose of the study was to collect data on background characteristics of students enrolled in General Biology at WC_3. These data were sex, age, race, marital status, parents' occupation, parents' education, number of siblings, math ability, reading ability, and cognitive development level. The data were then analyzed to determine how they affected achievement in science education.

More specifically the research design was developed to:

(1) Examine and analyze the students' background characteristics and their reading and math abilities as they relate to the students' cognitive development.

(2) Examine and analyze the students' background characteristics and their reading and math ability as they relate to the students' achievement in science education.

(3) Examine and analyze the students' cognitive development as it acts as a mediating variable between the students' background characteristics, and their reading and math ability with their achievement in science education.

(4) Establish a predictive equation to identify students who may not succeed in science education.

The research paradigm of the study is shown in Figures 1, 2 and 3. The general plan of the study was to collect the demographic data from the students by a questionnaire, the College Biology Student Survey, designed and administered by this researcher. Reading ability, scored as the grade level, was determined by the Nelson Denny Reading Test, Form F. Math ability, given in standard scores, was determined by the College General Placement Applied Arithmetic Test. Cognitive development was assessed by The Inventory of Piaget's Developmental Tasks (IPDT). It determines the students' level of cognitive development. The IPDT is pictorial and has a minimal reading level so reading ability does not become a factor in taking the test. The IPDT assesses five problem area skills, Relations, Imagery, Conservation, Classification and Proportional Reasoning. These skills are necessary for attaining the formal level of cognitive development. Achievement in the General Biology course was determined by the letter grade assigned to the students by the instructors.

Other demographic data of interest to this researcher were ascertained by the questionnaire. These variables were: working experience(s) past and present, number of hours worked per week, financial resources, family income, number of children, if any, number of credit hours, math

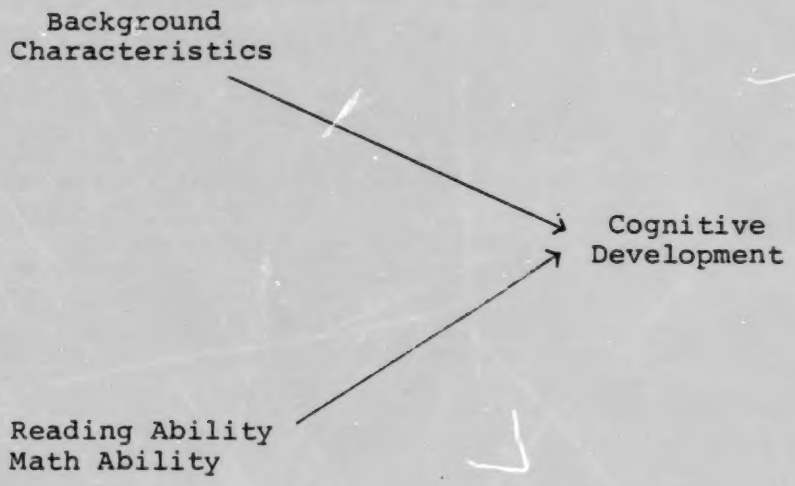

Background
Characteristics
Cognitive
Development
Reading Ability
Math Ability

Figure 1. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability and Cognitive Development.

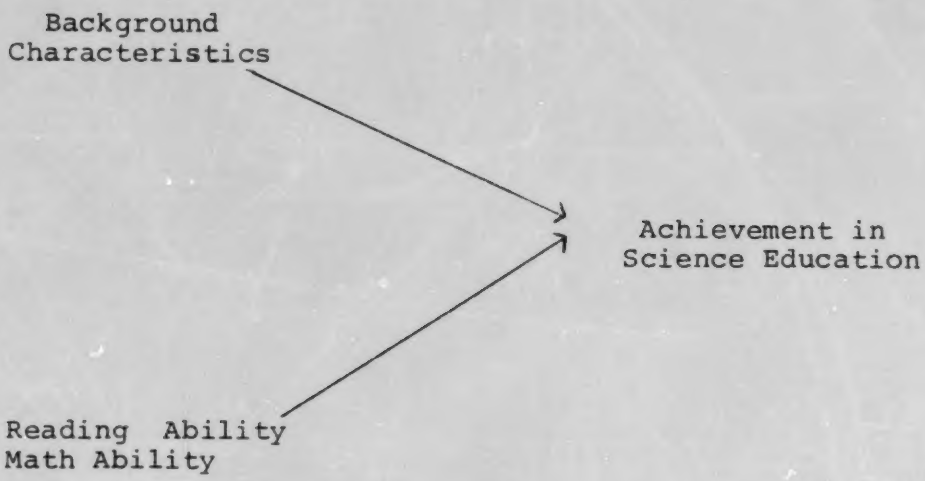

Background
Characteristics
Achievement in
Science Education
Reading Ability
Math Ability

Figure 2. Paradigm of the Relationship Between Background Characteristics and Reading Ability, Math Ability Achievement in Science Education.

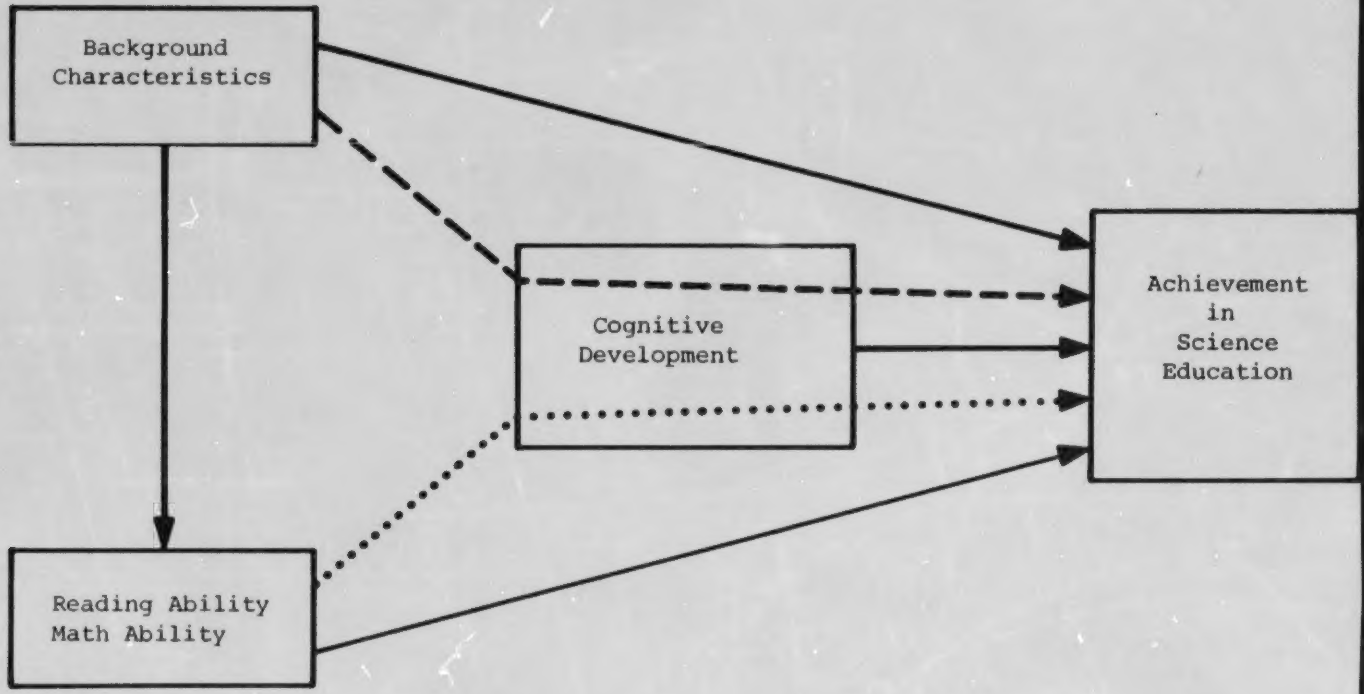

Background Characteristics
Cognitive Development
Achievement in Science Education
Reading Ability
Math Ability

Figure 3. Simple Paradigm Showing Relationships of Variables.

and science classes passed in high school and college, programs enrolled in, and reasons for attending WC_3.

Rationale for Selecting the Variables.

The needs and abilities of the students in the WC_3 General Biology course are varied and diverse. Students bring their life experiences to class with them. The literature noted differences in the life experiences of the adult learner at the community college from the life experiences of the traditional university student. Certain factors (variables) from these life experiences had an impact on cognitive development, grade and attrition. These variables are: sex, age, race, marital status, parents' education and occupation, reading ability and math ability or rather lack of math ability frequently expressed as a fear or dislike of math, inability to reason backwards (reversibility), to reason abstractly or to reason combinatorially.

Readings from the literature suggested that these variables did indeed play a role in cognitive development, attrition and achievement. However, the literature showed a dichotomy. Some readings showed a direct relationship between these variables and achievement and cognitive development; others did not show this relationship. The dichotomy from the literature piqued this researcher's curiosity and led in part to the research study.

Research Hypotheses.

The following research hypotheses were proposed:

Research Hypothesis One: A positive and direct relationship exists between the students' background characteristics and the cognitive skills the students have attained.

Research Hypothesis Two: A positive and direct relationship exists between the students' background characteristics and their achievement in science education.

Research Hypothesis Three: A positive and direct relationship exists between the students' reading and math ability and the cognitive skills the students have attained.

Research Hypothesis Four: A positive and direct relationship exists between the students' reading and math ability and their achievement in science education.

Research Hypothesis Five: A positive and direct relationship exists between the students' cognitive skills and their achievement in science education.

Research Hypothesis Six: A positive, direct linear relationship exists between the students' background characteristics, their cognitive skills and their achievement in science education.

Research Hypothesis Seven: A positive, direct linear relationship exists between the students' reading and math ability, their cognitive skills and their achievement in science education.

Research Hypothesis Eight: A positive, direct additive linear relationship exists between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

Research Hypothesis Nine: Cognitive development is an intervening variable between the independent variables, background characteristics, reading ability, math ability and the dependent variable, achievement in science education.

Research Hypothesis Nine A: There is a direct effect of cognitive development on achievement in science education independent of the overlapping effects of background characteristics, reading ability and math ability.

Research Hypothesis Nine B: There are direct effects of the background characteristics, reading ability and math ability on achievement in science education.

Research Hypothesis Nine C: There are indirect effects of background characteristics, reading ability and math ability on achievement in science education mediated by cognitive development.

Assumptions of This Study.

(1) Students would answer the questionnaire and the three test instruments to the best of their ability.

(2) Biology instructors would cover similar topics as predetermined by the course syllabus.

(3) The students' cognitive development could be measured by a paper and pencil test instrument.

(4) Achievement could be measured by the course grade.

Limitations of the Study.

(1) Even though the classes were randomly selected, students were self selected into their classes.

(2) Each biology instructor tests his/her own class and assigns the grade independently.

(3) Inferences cannot be made to the community college General Biology population.

(4) Inferences can be made to WC_3 General Biology students.

Significance of the Study.

Results from this research study could be utilized to develop a diagnostic test or tests to determine the students' academic strengths and weaknesses. A predictive equation could be formulated which counselors and General

Biology instructors at WC_3 could use to identify those students who most probably would not succeed in the General Biology course. These students could then be given tutoring, additional help and/or be placed in a remedial program.

Information from this research study can also be used as a rationale for developing a remedial biology course or for extending the current one semester course into a two semester course.

Summary.

WC_3 is a large urban community college with an open door policy which serves a heterogeneous student population. This study looks at the diversity of the General Biology students. The relationship of General Biology students' background characteristics, reading and math ability and cognitive development level to achievement in science education will be examined. The goal of this study is to identify high risk students by formulating a prediction equation using the above variables.

In Chapter II, the literature relating background characteristics, reading and math ability to the cognitive development level and to achievement in community colleges and, in particular, to science education at community colleges is presented.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Introduction.

Literature in educational research shows a continuing quest to determine factors which influence the students' scholastic achievement. Factors from DNA to environment have been explored for their relationship to achievement. Background characteristics, reading and math ability and cognitive development are factors which this researcher has deemed important and appropriate as determinants of the students' ability to achieve in science. Thus the review of the literature focused on the background variables and cognitive development as related to achievement in science education.

The Relationship of Background Characteristics to Achievement in Community College Students.

According to Bell (1966), Foxworth (1970), and Merritt (1972), the best predictors for success in a community college are sex, age, marital status and family income. Married students, male and female, performed better than their single counterparts but single females performed better than single males.

Reyes (1975) concluded that the student most likely to succeed at a community college will be a female, high school graduate, approximately 27 years old, in a liberal arts transfer program. Childs (1979) agreed that community college students 28 years or older were more likely to be high achievers than younger students.

According to Herridge (1971), the higher achievers in community colleges are older, predominantly white, married with children, work full-time and attend college part-time.

Ngo (1972) and Griffin (1978) found that females are more likely to have a higher GPA than males. They also conclude that older students and married students have a higher rate of achievement than younger students and single students.

However, Smoke (1955), Spector (1966) and Lindia (1971) found no relationship between sex, marital status and number of siblings on achievement.

Reyes (1975) and Griffin (1978) concurred with Spector (1966) that minority students as a group were not more likely to have a lower GPA than non-minority students.

Hay and Linsay's (1975) review of the literature on working college students concluded that part-time employment does not adversely affect achievement. In contrast, their study concluded that students who worked 16 hours or more per week had consistently lower GPA's than did the non-working students.

The fathers' level of formal education was a significant factor in predicting academic success according to Bossone (1965), Herridge (1971) and Fleming (1972). But Lindia (1971) found no significant relationship between father's educational level and student achievement.

The Relationship of Background Characteristics to Achievement in Science Education.

Jenkins (1966), Bennett (1970), Croft (1972) and Demas (1977) found no significant relationship between sex and achievement in freshman biology while Spurlin (1968) and Moss (1979) found that sex bias effects are present. Durst (1968) concluded that male students scored significantly higher than females in college biology.

Emmeluth (1979) found that males achieved better than females. He also found that older students achieved better than younger students in college biology. Demas (1977) concurred that there is a significant relationship between age and achievement.

Demas (1977) found that married students were more likely to achieve in college biology than single students.

McCall (1972) found that students who were employed part-time achieved significantly higher than those who worked full-time or those who did not work. In contrast, Williams (1972) found no correlation between working, full or part-time, and achievement in college biology.

The relationship of background characteristics to achievement in community college science education is not clear. A dichotomy is found in the literature on many factors. Further research is necessary to resolve these conflicts.

Piagetian Cognitive Development.

Piaget has defined four basic sequential stages of development starting from birth: the sensory motor from 0 - 2 years, the preoperational from 2 - 7 years, the concrete operational from 7 - 12 years or older, and the formal operational from 12 - 17 years or, more recently, 15 - 16 years to adult (Padilla, 1978). However, Piaget cautions that "there are no static stages as such. Each is the fulfillment of something begun in the preceding one and the beginning of something that will last on to the next (Dyli: 25)." Piaget also states that "the speed of development can vary from one individual to another and also from one social environment to another (Piaget, 1972:2)."

Since this research study is concerned with students 18 years or older, only the concrete and formal stages of cognitive development will be discussed.

According to Piaget, to reach a new level of cognitive development, one must successfully pass through each successive stage. Four factors influence the progression through these levels: maturation, physical experience, social experience, and equilibration.

In order to assimilate and accommodate the physical and social experiences into a mental construct or operation, a person must equilibrate. Sund (p. 13) states:

> "Equilibration is a mental, self-regulating process consisting of assimilation and accommodation. Assimilation involves absorbing information and incorporating it into mental schemes. Accommodation is the process of fabricating or modifying existing mental schemes. The schemes produced as a result of equilibration are general mental or organized patterns that the mind is capable of manifesting when the environment or will demands."

According to Piaget, a high school graduate should have reached the fourth stage of cognitive development, the formal operations stage. In order to accomplish this, he/she must have successfully passed through the third stage, concrete operations.

In the concrete operations stage, thought is restricted to what can be encountered in a direct experience. According to Padilla (1978), the mental operations developed in the concrete stage are:

(1) Logical problems can be understood and solved through manipulation of concrete objects or experience only.

(2) Actions and operations can be mentally reversed.

(3) Objects can be ordered and classified.

(4) Objects do not change in volume, weight or number when they are spatially rearranged (conservation).

Piaget states:

> "Concrete logical operations are actions performed on objects to bring them together into classes of various orders or to establish relations between them. One can also distinguish infralogical operations from concrete classifications or relational operations, their function is to integrate the parts of objects into a spatio-temporal whole (Piaget, 1958:273)."

In the formal-operational stage, thought is systematic and involves logically complex processes. It is abstract and manipulation of objects is no longer essential. According to Padilla, the mental operations developed in the formal stage are:

(1) Interaction in the hypothetical.

(2) Formulation and testing of hypotheses by identifying and controlling variables.

(3) Generation of multiple possibilities.

(4) Reflection on his/her own thought processes.

(5) Solving problems using proportional thought.

> "The principle novelty of this period (formal operations) is the capacity to reason in terms of verbally stated hypotheses and no longer merely in terms of concrete objects and their manipulation ... Hypothetical reasoning implies the subordination of the real to the realm of the possible, and consequently the linking of all possibilities to one another by necessary implications that encompass the real, but at the same time go beyond it (Piaget, 1972:4)."

According to Piaget (1972: 10), "all normal subjects attain the stage of formal operations or structuring if not between 11 - 12 to 14 - 15, in any case between 15 - 20 years. However, they reach the stage in different areas according to their aptitudes and their professional specializations."

Relationship of Background Characteristics to Cognitive Development.

According to Piaget, formal thinking should be achieved between 15 and 20 years of age. However, Lowell, Chiappetta, Renner, Cowan, Sund, Karplus, Lawson, Herron and others state that over 50% (50% - 85%) of American adults have not reached the formal level of development.

Miller's (1975) study demonstrated that at the formal level, differences could not simply be attributed to race or age. Experience, including cultural and socioeconomic influence, does affect cognitive processes. Karplus (1977) confirmed that there is a direct positive correlation between SES and the ability to perform proportional reasoning. Goolishian (1981) showed that their mothers' level of education was related to the students' cognitive development.

Karplus (1977) and Brendzel (1978) found that females were poorer than males in proportional reasoning. Delahanty (1977) and Kelly (1977) agreed that males were more advanced than females. Milakofsky (1982) found that on the IPDT males significantly outperformed females in conservation and proportional reasoning. Williams, et al. (1979) found that males scored higher than females on the Logical Reasoning Test. In contrast, Goolishian (1981) determined that females performed significantly better than males on the cognitive development test.

Tomlinson-Keasey (1972) and Coleman (1973) determined that cognitive ability declined with age (54 - 84). However, Hooper (1971) found that increments in intellectual abilities exist in some subjects until at least the mid-fifties.

Thus, numerous studies have concluded that sex and age play significant roles in attaining the formal level of development. Evidence also suggests that race, SES and life experiences affect cognitive development.

In Piaget's article on "Intellectual Evolution from Adolescence to Adulthood," he posits a rationale for the inability of some adults to achieve formal operations.

> "Briefly, our first interpretation would mean that in principle all normal individuals are capable of reaching the level of formal structures on the condition that the social environment and acquired experience provide the subject with the cognitive nourishment and intellectual stimulation necessary for such a construction.
>
> "However, a second interpretation is possible which would take into account the diversification of aptitudes with age ... We would go so far as to say that certain behavior

> patterns characteristically form stages with very general properties: this occurs until a certain level in development is reached; from this point onwards, however, individual aptitudes become more important than these general characteristics and create greater and greater differences between subjects ... In other words, our fourth period can no longer be characterized as a proper stage but would already seem to be a structural advancement in the direction of specialization (1972:8)."

Piaget concludes his article asking and then partially answering his own question.

> "The period from 15 to 20 years marks the beginning of professional specialization and consequently also the construction of a life program corresponding to the aptitudes of the individual. We now ask the following critical question: Can one demonstrate, at this level of development as at previous levels, cognitive structures common to all individuals which will, however, be applied or used differently by each person according to his particular activities?
>
> "The reply will probably be positive but this must be established by the experimental methods used in psychology and sociology. Beyond that, the next essential step is to analyze the probable processes of differentiation; that is to say, whether the same structures are sufficient for the organization of varying fields of activity but with differences in the way they are applied, or whether there will appear new and special structures that still remain to be discovered and studied (1972:15)."

The Relationship Between Reading and Math Ability and Cognitive Development.

Piaget's theory of cognitive development is based on logic and mathematics. He believes that certain logico-mathematical structures make very good models of the actual organization and process of cognition.

According to Flavell (1963):

> "Mathematics is involved in both the structure of the theory and in the content of the experimental work. The theory of intellectual development makes use of logico-algebraic systems-groups, lattices, and groupings -- in its treatment of intellectual structure. Similarly, the perception theory is definitely a quantitative affair involving equations with variables and constants which take their values from experimental data. It seems to be true that Piaget strives always to give mathematical-logical expression to theoretical constructs whenever the latter lend themselves to such treatment. Moreover, he tries to select the kind of expression most appropriate to the behavior formalized: qualitative and non-numerical algebra for conceptual structures; quantitative equations for certain aspects of perceptual functioning (p. 34)."

Wadsworth (1978) states that "Piaget has never done any research on reading and except for stressing movitation, has no opinion (p. 127)." However, Wadsworth emphasizes that Piaget's theory suggests several considerations for reading:

> "Within a Piagetian framework, one can conceptualize the child as approaching the task of learning how to read in the same manner in which the child intuitively approaches any situation. The child confronted with graphic symbols that do not make sense to him tries to assimilate and accommodate these symbols in an effort to make sense out of the written aspects of language. The child tries to 'break the code' that words and sentences present. The child tries to organize and integrate into his cognitive structures the reading process. As with other learnings, learning to read is a process of construction. The child internally gives

> increasingly more accurate structure to the written aspects of representation (p. 126)."

Several research studies have clearly shown the relationship between cognitive development and reading and math ability.

Raven, Hannah and Doran (1974) defined reading comprehension as the ability to associate concepts and to relate these concepts in various ways. The Iowa Silent Reading Test and Raven's Test of Logical Operations to measure cognitive ability was administered to 123 black college freshmen enrolled in an introductory physical science course. The reading test was significantly related to cognitive development and explained 25% of the variance of cognitive development.

McKinnon and Renner (1971) found a significant relationship between the level of cognitive development and the ACT verbal and math scores for the above average students but no significant relationship was found for below average students.

Milakofsky and Bender (1981) concluded that a relationship exists between the IPDT and SAT verbal and math scores from a research study of 225 introductory/remedial college chemistry students. The correlation between the IPDT and the SAT math score was much higher than the correlation with the IPDT and SAT verbal scores.

The Relationship of Reading and Math Ability to Achievement in Community College Students.

Most of the literature showed a direct positive correlation between reading and math ability generally measured by the SCAT, SAT and ACT and achievement in community college students.

Foxworth (1970), Curran (1971), Merritt (1972) and Nagle (1976) concluded that reading and math scores showed a significant relationship to achievement in community college students.

However, Reyes (1975) disagreed and showed that reading and math test scores were not able to predict achievement. Beach (1968) also concluded that the usual academic predictors of college success such as high school GPA, class rank and SAT scores, are of no use in predicting the first year cumulative GPA of marginal students.

The Relationship of Reading and Math Ability to Achievement in Science Education.

Spurlin (1968), Emmeluth (1979) and Geis (1979) determined that scores on the Nelson-Denny Reading Test were significantly related to achievement in introductory college biology courses.

Jenkins (1966) concluded that while the rank in the students' high school graduating class is the best predictor, reading ability is the second best predictor of academic success in introductory college biology.

Chesson (1974) reported that the CGP reading score and the CGP mathematics score can predict successful achievement in science education.

Demas (1977) showed a direct significant relationship between ACT English and math scores and achievement in college biology.

Milakofsky and Bender (1981) found little correlation between SAT verbal and math scores and achievement in students taking a remedial college chemistry course. However, in an introductory chemistry course, a significant correlation was found between SAT reading and math scores and achievement. The math scores correlated much higher with achievement than did the verbal scores.

Relationship of Cognitive Development to Achievement in Science Education.

The majority of American adults do not attain the formal level of cognitive development. Since most General Biology courses are taught abstractly at the formal level, then the students' level of cognitive development could affect their achievement in science education.

According to Padilla (1978), formal students achieve considerably higher than concrete students in science education.

Cantu and Herron (1978) agreed with Padilla that formal operational students will attain abstract concepts better than concrete operational students. Their study showed that formal operational students achieve better than concrete operational students in chemistry.

Chiappetta (1976) and Lawson (1974) showed that formal operational students achieved significantly higher scores in science as a result of concrete instruction than they did from formal instruction.

Bender and Milakolsky (1982) demonstrated that the "A" student had a higher level of measured cognitive ability than did the other students. They also showed a positive correlation between the IPDT and achievement in a college chemistry course.

However, Albanese, et al. (1976) concluded that performance on written Piagetian tasks was not highly correlated with achievement and could explain little of the variance in the grade for introductory college chemistry.

This researcher agrees with the following statement by Padilla (1978, p. 8):

> "If a great number of our students are not formal operational, even by grade 12, and if concrete operational students do not learn formal concepts, then this leaves us with two alternatives. We can either concentrate on concrete concepts at the expense of the more abstract ideas of science or we can attempt to develop new teaching procedures that use concrete examples, models and other materials as much as possible in the hopes that a more concrete approach will prove successful (Padilla, 1978, p. 8)."

Summary of the Research.

Most of the research studies relating cognitive development to achievement in science education involved students at the primary and secondary educational levels. Few studies assessing the cognitive development of the community college students have been conducted. Fewer studies relating cognitive development to achievement at the community college level have been researched. There exists a paucity of literature on these topics. One of the purposes of this research study is to assess the cognitive development of community college science students; another is to examine the relationship between cognitive development and achievement in science education. Hopefully this research study can contribute some information to "flesh out" the sparse information currently available.

The description of the students who voluntarily participated in the study, the test measures and the data collection method used in the study are presented in Chapter III.

CHAPTER III

RESEARCH PROCEDURES

This chapter describes the methods, procedures and instruments utilized in conducting this study.

Selection and Description of the Sample.

This study was conducted at WC_3 which has five geographic, autonomous regional centers/campuses. Permission to allow WC_3 General Biology students to participate voluntarily in this study was obtained from the Council of Regional Deans (see Appendices A and B).

Initially, four General Biology courses were randomly selected from each region using an appropriate statistical procedure (see Appendix C). Each instructor's permission was obtained to allow his/her class to participate in the study.

The students from each selected class were asked to participate voluntarily in the study. Of the 467 students who initially participated, 420 students completed all the instruments. The students ranged from the traditional aged college student, 17 - 22 (39%) to the non-traditional college student, 22 - 60+ (61%). The median age of the studentswas 26. Classes were comprised of 82% females and 18% males. The students were racially balanced: 49% were white, 51% were non-white. Seventy-one percent of the students were single, divorced, widowed or separated; 29% were married. Eighty-four percent had graduated from high school. Seventy-eight percent were taking nine or more credit hours during the Fall, 1981, semester. Fifty-two percent were employed and of those employed, 77% worked 20 hours or more per week.

Description of the Test Measures.

The College Biology Student Survey. This survey was designed by this researcher to measure the students' demographic data. It was pretested four times with appropriate modification after each pretest. These modifications were made after consulting with the students, other instructors who administered the survey, and Dr. Alfred, Dr. Davidson and the other members of my Dissertation Committee. The students determined that the final form of the questionnaire was non-threatening, non-embarrassing, readable, understandable and easy to follow. When the final form of the survey was pretested, all the students answered all the questions (see Appendix D).

An Inventory of Piaget's Developmental Tasks. An inventory of Piaget's Developmental Tasks (IPDT) was developed by Dr. Hans Furth and Dr. Burton Ross of the Center for Research in Thinking and Language in the Department of Psychology of the Catholic University of America. The IPDT was designed to be used with Navaho children and was later used with deaf children. The Tasks are pictorial and have a minimal reading level. Therefore, reading ability is not a factor in taking this test. The IPDT is untimed. Most students finished in 35 to 45 minutes though a small number required up to an hour to complete the IPDT. The IPDT is a 72-item multiple choice paper and pencil instrument (see Appendix E). Each item has one correct answer out of four possible choices. It is designed to inventory the student's cognitive development skills. These skills are divided into 18 Tasks or subtests with four items per Task. Each Task is preceded by an answered example question. "The first question in each Task was intentionally made very easy so that a practice function was served and a check was possible on whether an individual had understood the Task (Ross, 1968)." Subsequent Tasks are as difficult or more difficult than previous Tasks assessing the same skill. If a student answered three out of four items correctly, that student was assessed to have developed that cognitive skill or Task (personal communication with Dr. Ross, February, 1982).

According to Patterson and Milakofsky (1980), "the criterion of 75% or more correct responses on items in a subtest (i.e., at least three out of four items) is used to define mastery of a subtest concept."

According to Dr. Ross (1968), some of the Tasks were literal translations of traditional Piaget experimental tasks into a paper and pencil format such as conservation of weight and volume and perspective while others involved somewhat novel adaptations.

The eighteen Tasks or subtests of the IPDT, the problem area and concept assessed are summarized in Table 1.

"The Inventory is divided into five problem areas: classification, relations, images, laws and conservation (Ross, 1968)." Relations and Imagery are represented by three Tasks. Conservation, Classification and Proportional Reasoning are represented by four Tasks. The 18 Tasks which are divided into the five problem area skills are summarized in Table 2.

Reliability.

Patterson and Milakofsky determined the reliability of the IPDT using test-retest reliability based on the coefficient of stability. They correlated total IPDT group test scores for eight groups (N = 542: 250 third, sixth and ninth grades; 210 college freshmen and sophomores and 60 adults in college continuing education) on two

Table 1. Summary of the IPDT

Task Number	Task Name	Problem Area	Concept Assessed
1	Quantity	Conservation	Conservation of Quantity
2	Levels	Images	Maintaining a Liquid Horizontal to General Horizontal Plane
3	Sequence	Relations	Ordinal Seriation
4	Weight	Conservation	Conservation of Weight
5	Matrix	Classification	Double (Horizontal and Vertical) Classification
6	Symbols	Classification	Classification Additive
7	Perspective	Images	Perspective of Other Person
8	Movement	Images	Movement Progression
9	Volume	Conservation	Conservation of Volume
10	Seriation	Relations	Seriation of Height
11	Rotation	Laws	Prediction of Gear Movement in Opposite Directions
12	Angles	Laws	Reciprocal Implications
13	Shadows	Laws	Shadow Perspective
14	Classes	Classification	Color, Size and Shape Classification
15	Distance	Conservation	Conservation of Distance
16	Inclusion	Classification	Verbal Classification
17	Inference	Relations	Verbal Transitivity
18	Probability	Laws	Probability

Table 2. Problem Area Skills

Relations	Imagery	Conservation
Sequence	Levels	Quantity
Seriation	Perspective	Weight
Inference	Movement	Volume
		Distance

Classification	Proportional Reasoning
Matrix	Rotation
Symbols	Angles
Classes	Shadows
Inclusion	Probability

administrations of the group test one month apart. The r for the college groups was 0.95 and 0.67.

Split-half reliability using the Spearman-Brown Formula yielded a reliability coefficient of 0.77 in samples of college students.

According to Patterson and Milakofsky (1980) these reliability data correspond closely to reliability studies on other Piaget tests by Lawson (1977) and Sheehan (1970). Their general conclusions concerning reliability:

> "are that the IPDT scores are reasonably stable over a short period for a wide range of age groups and that scores are not seriously affected by situational testing variables. Furthermore, the inventory has considerable internal consistency and appears to be measuring a lasting trait rather than a specific temporary trait (p. 348)."

The Applied Arithmetic Test. The College General Placement Applied Arithmetic Test (CGP) is a standardized test developed by the College Entrance Examination Board. It is a 20-minute test which consists of 25 multiple choice questions. Each question has one correct answer out of four possible choices. The test is designed to assess the ability of the student to solve problems relating to percentages, proportions, ratios, rates, and averages. It also assesses the ability of the student to interpret data involving graphs and charts. According to the CGP manual (1979), "an acceptable score could indicate that a student is ready for a course whose only mathematics prerequisites are computational skills and problem solving ability (p. 6)."

The scoring was standardized with a norming group of 30,912 college freshmen. The average score was set at 50. About two-thirds had scores between 40 and 60.

Reliability.

The reliability of the test was determined by using the Kuder-Richardson Formula 20. Using this method, the reliability coefficient was 0.83.

Validity.

The content validity was determined by mathematics experts. They identified the skills necessary for success in mathematics courses as taught in postsecondary institutions with an open admissions policy.

The Nelson-Denny Reading Test Form F. The Nelson-Denny Reading Test, Form F, is a standardized test developed by the Houghton Mifflin Company. It is a timed test. The Vocabulary section requires 15 minutes and the Comprehension section requires 20 minutes. The total test time is 35 minutes.

The scoring was standardized with a norming population of over 6,000 students from two-year colleges, 5,000 students from four-year colleges and universities and

14,000 students from 80 high schools. The grade equivalent score on this test ranges from 3.6 and 16.9.

Reliability.

The reliability of the test was determined by the alternative form reliability method. Using this method, the reliability coefficient for the Vocabulary section was 0.92. The reliability coefficient for the Comprehension section was 0.77.

Validity.

Context Dependence (CD1) is the validity measure used in this test. This kind of validity is important in a test containing interpretative exercises such as reading comprehension items. According to the Examiner Manual (1981), the CD1 measures the degree to which correct item responses are under the influence of the context. The CD1 is expected to be positive and significant. The CD1 for the reading test was 0.44. "The Context Independence (CI1) measures the degree to which examinees can answer the item through previous knowledge or the application of logic that does not require the context ... Context independence is an undesirable item characteristic and the CI1 is ideally zero or negative (p. 17)." The CI1 of Form F was 0.03.

Description of Achievement in Science Education.

The Life and Physical Sciences Department has a syllabus and course outline for the General Biology course. These documents describe the topics which must be taught in the course. However, instructors have some academic freedom. They decide the method, time and testing of these prescribed topics.

The instructors also determine their grading policy within the guidelines established by WC_3 academic policy.

"The academic policy on grading is (Wayne County Community College Catalog, 1981-83:44):

1. Grades indicating course completion with credit and recorded on the official transcript:
   - A Excellent
   - B Above Average
   - C Average
   - I Incomplete
2. Grades indicating course completion with no credit and recorded in the computer transcript file and grade reports only:
   - D Poor (Below Average)
   - E Failure to complete course requirements satisfactorialy
   - WP Indicates official withdrawal only
   - WI Indicates official withdrawal by institution. Failure to attend any class during the first five weeks of the semester

3. Satisfactory completion of a course is a grade of "C" or above. Grades below "C" do not count toward degree requirements or transfer credit."

This researcher requested the grading policies of the instructors who allowed their classes to participate in the study. With few exceptions, the majority of the instructors' grading policies were based on averaging the test scores (four to six instructors made tests) and assigning a grade based on the averaged points. The point-grade system is: 90 - 100 = A; 80 - 89 = B; 65 - 79 = C; 60 - 64 = D; Below 60 = E. Two instructors graded on the normal bell shaped curve. One instructor had a written report included with the test scores.

Data Collection.

The students in each selected class were asked to voluntarily complete the following forms:

(1) College Biology Student Survey
(2) An Inventory of Piaget's Developmental Tasks (IPDT)
(3) The CGP Applied Arithmetic Placement Test (CGP)
(4) The Nelson-Denny Reading Test, Form F

These procedures were conducted in two one-hour segments during separate class periods to prevent student fatigue. The survey and the IPDT were administered during the first hour of one class period. The CGP and the Nelson-Denny Reading Test were administered during the second class period. Weekday classes meet for two hours twice a week. The three Saturday classes were the only exceptions. Since these classes meet for four hours each Saturday of the semester, the procedures were administered in two one-hour segments with a break between the segments.

The students were told explicitly that their participation was voluntary in whole or in part and that they might choose not to answer a particular question(s).

The students were assured that all the results would be confidential. To maintain this confidentiality, they were asked to use their social security number on all forms. Each student's social security number was given a code by this researcher so that individual results were unidentifiable.

All the students who participated in this study signed consent forms (see Appendix F).

In two of the five regions (the Downtown Region and the Greenfield Region), 50% to 70% of the students in two classes decided not to participate in the study. A minimum of 80 students from each region was necessary to conduct the statistical tests. Additional General Biology classes from these two regions were selected randomly following the method described in Appendix C. This ensured equal representation from all regions. A total of 22 General Biology classes participated in this study.

When this researcher invited the voluntary participation of the students in the first two classes scheduled for testing, several students declined to participate and informed the researcher that "there was nothing in it for them."

In order to encourage participation, this researcher informed the remaining classes that interested students could be informed of their individual test scores by giving their instructor an envelope with their social security number written on it. The instructor then forwarded these envelopes to this researcher. The tests were scored and the results of those students who gave envelopes were written on a form letter (see Appendix G), placed in the envelopes and the envelopes were returned to the instructors for distribution. Confidentiality was maintained, but more students were motivated to participate because there was something in it for them.

This chapter described the selection and characteristics of the students who participated in the study, the description of the test measures and the method used in the data collection.

Following the collection of the data, the data were collated and processed for statistical analyses. The analyses of the data are reported in Chapter IV.

CHAPTER IV

ANALYSIS OF DATA

This chapter contains the data and the statistical analyses of the study. Research hypotheses and the appropriate null hypotheses are presented and tested. The level of significance (α) acceptable for the statistical tests is 0.05. This means that the probability of making a Type I error (rejecting the null hypothesis when it is true) could occur five times in 100 tests (Johnson, 1977). The significance level was set at 0.05 to reduce the probability of making a Type II error. A Type II error occurs when the null hypothesis is accepted when it is false. The probability of making a Type I error can be decreased by changing the significance level to 0.01. However, this increases the probability of making a Type II error.

Type I errors are a function of sample size and are reduced by a large sample. The N for this study is 420. Type II errors can also be reduced by the power of the statistical tests. Linear regression is a powerful statistical test because it is used with interval data in the dependent and independent variables.

> "Interval-level techniques are much more powerful than ordinal-level and nominal-level techniques. They permit us not only to measure how strongly related a pair of variables are but also to make a statement describing the effect of one variable on the other (Weisberg, 1977:196)."

It is a powerful statistical test because it can resist violation of the assumptions that the predicted (Y) values are assumed to be normally distributed and to have equal variances at each predictor (X) point (Kerlinger, 1973).

Some of the independent variables in the background characteristics are nominal data. If the nominal datum is a dichotomous variable (a variable on a two-point scale such as male, female), that variable can be treated as interval data (Andrews, 1981, Davidson, personal communication, 1981). Then linear regression can be used.

If the nominal datum is not a dichotomous variable, it can be changed into a dichotomous variable by the use of a dummy variable.

> "A dummy variable is a vector in which members of a given category are assigned an arbitrary number, while all others - that is, subjects not belonging to the given category - are assigned another arbitrary number ... They (dummy variables) can be used, for example, in combination with continuous independent variables ... When dealing with a categorical independent variable, one can express it appropriately with dummy variables and do a regression analysis with the dummy variables as the independent variables (Kerlinger, 1973:105,107)."

By having the significance level at 0.05 but with a large sample and by using dummy variables for nominal data, linear regression, a powerful statistical test, can be used. This reduces the probability of Type I and Type II errors.

Description of the Variables.

From the four test measures, the students' background characteristics, reading and math ability, cognitive skills and grades were obtained. To clarify this information, the descriptive measures of the variables, Relative Frequency Tables, were formulated.

The demographic data used in the statistical analyses are summarized in Table 3. The variables not used in the statistical analyses are summarized in Appendix H. The proportion of males to females enrolled in General Biology approximately reflects the proportion of males to females in the college. The racial proportion also reflects the racial balance in the school, therefore the data were not weighted.

Grouped according to age, the majority of the students (61%) are the non-traditional students, 39% of the students are the traditional college students, 17-22. WC_3 enrollment agrees with the statements of Cohen, Cross and Chickering concerning the age of the community college student.

It is interesting to note the bimodal distribution in total family income. Twenty-four percent of the students report income sources between $10,000 and $15,000; 32% of the students have incomes over $20,000.

Table 3. Summary of Demographic Data (N=420).

Variable	Category	N	%
Sex	Male	76	18
	Female	343	82
		420	100
Age	17 - 22	163	39
	23 - 30	126	30
	31 - 40	85	20
	41 - 50	32	8
	Over 50	13	3
		419	100
Race	White	206	49
	Black	197	47
	Other	17	4
		420	100
Marital Status	Single, Separated, Divorced, Widowed	296	71
	Married, Living Together	121	29
		417	100

Table 3 (continued)

Variable	Category	N	%
Fathers' Occupation	Professional	42	10
	Manager	47	11
	Sales	15	4
	Clerical	10	2
	Service	33	8
	Crafts	67	16
	Factory Worker	79	19
	Laborer	43	10
		336 (420)	80 (100)
Mother Employed	Yes, Full Time	155	37
	Yes, Part Time	53	13
	No	177	42
		385 (420)	92 (100)

Table 3 (continued)

Variable	Category	N	%
Mothers' Occupation	Professional	29	7
	Manager	10	2
	Sales	19	5
	Clerical	38	9
	Service	70	17
	Crafts	4	1
	Factory Worker	32	8
		202 (420)	59 (100)
Fathers' Education	Don't Know	64	15
	Elementary School	71	17
	Some High School	69	16
	Finish High School	80	19
	Technical School	38	9
	Some College	45	11
	Associate Degree	13	3
	Bachelor Degree	26	6
	Graduate School	14	3
		420	100

Table 3 (continued)

Variable	Category	N	%
Mothers' Education	Don't Know	47	11
	Elementary School	53	13
	Some High School	93	22
	Finish High School	114	27
	Technical School	16	4
	Some College	52	12
	Associate Degree	18	4
	Bachelor Degree	13	3
	Graduate School	14	3
		420	100
Number of Siblings	0	66	16
	1	114	27
	2	92	22
	3	78	19
	>3	70	16
		420	100

Students reported they attend WC_3 for numerous reasons. Their primary reason for attending WC_3 is to achieve a personal goal, such as Allied Health Programs, followed closely by a desire to improve themselves. Less important is WC_3's closeness to home and the programs offered by the college.

The reading and math ability scores are summarized in Table 4. Surprisingly, the students have an average reading level of the twelfth grade. Many instructors assumed WC_3 students had a ninth or tenth grade reading level. The CGP mean, 15 questions answered correctly, showed a lack of math ability. The CGP is the most elementary math test (about sixth grade level) available from the College Board. Only 16% of the students could answer 20 or more problems correctly out of a total of 25 possible correct answers.

The results of the 72-item IPDT are summarized in Appendix I.

The 18 Tasks of the IPDT are summarized in Table 5. When the results of the IPDT Tasks were ranked by percentage of students not having the skill, Tasks 9, Conservation of Volume, 11, Rotation, 12, Angles, 14, Classes and 15, Conservation of Distance, are the most difficult. Fewer than half of the students have skills in these areas.

Table 4. Summary of Reading and Math Ability (N=420).

Ability	Category	N	%
Reading	Third - Sixth Grade	31	7
	Seventh - Ninth Grade	56	13
	Tenth - Twelfth Grade	119	29
	Thirteenth - Sixteenth Grade	166	40
	Seventeenth Grade	47	11
		419	100
$\overline{X}$ = 12	S.D. = 3.48		
Math	1 - 5	13	3
(expressed in total number of correct answers on 25 question test)	6 - 10	80	19
	11 - 15	147	35
	16 - 20	112	27
	21 - 25	68	16
		420	100
$\overline{X}$ = 15	S.D. = 5.06		

Table 5. Summary of 18 IPDT Tasks (N=420).

Task	Have Ability*		Do Not Have Ability	
	N	%	N	%
1. Conservation of Quantity	304	72	115	27
2. Levels - Images	368	88	52	12
3. Sequence - Relations	324	77	96	23
4. Conservation of Weight	365	87	55	13
5. Matrix - Classification	375	89	45	11
6. Symbols - Classification	349	83	71	17
7. Perspective - Images	249	59	171	41
8. Movement - Images	232	55	188	45
9. Conservation of Volume	165	39	255	61
10. Seriation - Relations	386	92	34	8
11. Rotation - Laws	123	29	297	71
12. Angles - Laws	203	48	217	52
13. Shadows - Laws	238	57	182	43
14. Classes - Classification	50	12	369	88
15. Conservation of Distance	172	41	247	59
16. Inclusion - Classification	271	65	148	35
17. Inference - Relations	301	72	118	28
18. Probability - Laws	214	51	205	49

*Correctly answered 3 out of 4 subsets of the Task.

The Milakofsky and Bender (1981) test results were similar. They administered the IPDT to first-year chemistry college students attending a mid-size eastern commuter university. Their students' results showed Tasks 9, 11, 13, 14, 15 and 18 as the most difficult.

More than 70% of the students demonstrated their skills on Tasks 1, Conservation of Quantity, 2, Levels, 3, Sequence, 4, Conservation of Weight, 5, Matrix, 6, Symbols, 10, Seriation, and 17, Inference.

The chemistry students of Milakofsky and Bender also found Tasks 2, 3, 4, 5, 10 and 17 the easiest.

These results on the students' cognitive development agree with the Piagetian literature on the skills acquired first and last in the cognitive structure. Indeed, with a mean score of 49 successfully completed items, it can be clearly seen that most of the students are not at the formal level of cognitive development.

Examining the four individual items of the subtest on Conservation of Volume, the two items (35 and 36) dealing with the concept of water displacement showed the poorest results. Respectively, 56% and 69% of the students could not recognize that the amount of water displacement is a function of density and not mass.

In the Task, Rotation, students had difficulty in determining the proper position of gears after rotating one or more interlocking gears (items 41 and 42).

Sixty-three percent and fifty-seven percent of the students lacked this cognitive skill.

In the Task, Angles (item 45), 67% of the students showed the poorest results in determining the angles of incidence when bouncing a ball against a wall.

The Classification Task was the most difficult of all the Tasks. On all four items (53 to 56), 53% to 71% of the students could not group the objects by shape, color and size in a hierarchially classification.

The results of Milakofsky and Bender similarily showed that over 50% of the students did not have this cognitive skill.

Eighty-five percent of the students missed one item (60) on the Distance Task. This item required the student to understand that in a figure with a constant parameter, when the shape changes, the area changes. Ninety-seven percent of Milakofsky and Bender's students also missed this item. Therefore, this researcher believes this item is inappropriate and should be changed or eliminated from future tests.

The five problem area skills of the IPDT are summarized in Table 6. Students were the most proficient in Relations (59%), then Imagery (37%), Conservation (18%), Proportional Reasoning (11%) and least proficient in Classification (9%). According to Milakofsky and Bender (1982:209), "In the relations and imagery areas students

Table 6. Summary of Five IPDT Problem Area Skills (N=420).

	N	%
Relations		
Levels	368	88
Perspective	249	59
Movement	232	55
N Correct On		
3 Tasks*	247	59
2 Tasks	112	27
1 Task	46	11
0 Tasks	15	4
	420	101
*59% of the Ss have this skill.		
Imagery		
Levels	368	88
Perspective	249	59
Movement	232	55
N Correct On		
3 Tasks*	154	37
2 Tasks	146	35
1 Task	95	23
0 Tasks	25	6
	420	100
*37% of the Ss have this skill.		

Table 6 (continued)

	N	%
Conservation		
Quantity	304	72
Weight	365	87
Volume	165	39
Distance	172	42
N Correct On		
4 Tasks*	75	18
3 Tasks	114	27
2 Tasks	149	36
1 Task	66	16
0 Tasks	16	4
	420	101

*18% of the Ss have this skill.

Table 6 (continued)

	N	%
Classification		
Matrix	375	89
Symbols	349	83
Classes	50	12
Inclusion	271	65
N Correct On		
4 Tasks*	38	9
3 Tasks	199	47
2 Tasks	129	31
1 Task	38	9
0 Tasks	16	4
	420	100

*9% of the Ss have this skill.

Table 6 (continued)

	N	%
Proportional Reasoning		
Rotation	123	29
Angles	203	48
Shadows	238	57
Probability	214	51
N Correct On		
4 Tasks*	44	11
3 Tasks	99	24
2 Tasks	96	23
1 Task	113	27
0 Tasks	68	16
	420	101

*11% of the Ss have this skill.

demonstrated a high level of mastery; in proportional reasoning these college students had the most difficulty."

When the subtests which proved to be the most difficult for the students were removed from the calculations, the percentage of students having the skill was greatly increased. If the subtest on Volume is removed from the Conservation skill, 65% of the students demonstrate this cognitive ability. If the subtest, Classes, is removed from Classification, the percentage of students having this ability increases to 55%. If the subtest, Rotation, is removed from the Proportional Reasoning skill, 23% of the students demonstrate this skill.

The analyses on grades (see Table 7) were computed on earned and unearned E's grouped together. This distinction was made because sometimes students come to class for several weeks, fail to drop the class officially, and therefore must be given an E (unearned) as a grade. An E that is earned means the student attended classes, took and failed the tests thereby earning an E. The mean grade in the General Biology course is a C+. Sixty-seven percent of the students who participated in this study earned a B or better in General Biology. This high rate of success may be attributed to the voluntary participation of the students. Marginal or poor students may have self-selected themselves out of the study. Difficulty in obtaining student participation from two regional centers was noted in

Table 7. Summary of Grades (N=420).

Grades	(Honor Points)	N	%
A	(4.0)	137	33
B	(3.0)	142	34
C	(2.0)	64	15
D	(1.0)	23	6
E	(earned)	17	4
E	(unearned)	27	6
I		7	2
WP		2	--
WI		1	--
		420	100

$\overline{X} = 2.7$.

Chapter II. These two centers were the inner city centers where many of the students could be expected to have marginal academic skills. Students who were failing may have dropped out before their class was tested. The high percentage of good grades could be attributed to good teaching or the grades could have been inflated by some instructors since the course tests are not standardized.

Analysis of the Data.

In these bivariate analyses, cognitive skills are classified in two ways:

(1) The total number of correct answers on the Inventory of Piaget's Developmental Tasks (IPDT).

(2) The five problem area skills as explained in Table 2, Chapter III, page 35.

The bivariate statistical analyses were performed on the total number of correct answers on the IPDT and on each individual problem area skill.

Simple linear regressions were computed for bivariate analyses. Multiple linear regressions were computed for the multivariate analyses.

The effect that a change of the independent variables has on the dependent variable can be measured by regression analysis. The regression coefficient (b or beta) measures how much the dependent variable is expected to change on the average with a unit change in the independent variable

(Johnson, 1977; Weinberg, 1977). The intercept constant, a, measures the point of the line where the independent variable intercepts the dependent variable. The independent variable measures 0 at this point.

The equation for a single linear regression, $Y' = a + bX$, can be expanded for multivariate analysis to $Y' = a + b_1X_1 + b_2X_2 + \ldots b_kX_k$. "In all regression problems, simple and multiple, the principle of least squares is used. In any prediction of one variable from another, there are errors of prediction ... The principle of least squares tells us, in effect, to so analyze the data that the squared errors of prediction are minimized (Kerlinger, 1973:30)."

To summarize the accuracy of a prediction and to demonstrate explicitly the magnitude of the relationship, the R, coefficient of multiple correlation, is calculated. The square of the multiple correlation coefficient, R^2, indicates the proportion of the variance of the dependent variable that is explained by the linear prediction from the independent variable.

The F-ratio determines whether the regression of X's on Y's is significant.

Analyses of Background Characteristics.

The background characteristic variables on which the bivariate analyses were calculated are: age, sex, race, marital status, parents' education, parents' occupation and number of siblings.

The variables, sex, race, marital status, parents' occupation and education, are nominal variables. These variables were calculated as dummy variables when used in a linear regression.

Research Hypothesis One.

A positive, direct relationship exists between the students' background characteristics and the cognitive skills the students have attained.

Hypothesis 1.1a: There is no significant difference between the students' sex and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 11.055 ($\alpha = 0.00$). The proportion of explained variance was 2.4%.

Hypothesis 1.1b: There is no significant difference between the students' sex and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was accepted. The F-ratio was 0.985 ($\alpha = 0.32$).

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 12.159 ($\alpha = 0.00$). The proportion of explained variance was 2.6%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 6.083 ($\alpha = 0.01$). The proportion of explained variance was 1.2%.

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 1.460 ($\alpha = 0.23$).

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 23.188 ($\alpha = 0.00$). The proportion of the explained variance was 5.1%.

Hypothesis 1.2a: There is no significant difference between the students' age and their total score on the IPDT.

This hypothesis was accepted. The F-ratio was 3.0266 ($\alpha = 0.08$).

Hypothesis 1.2b: There is no significant difference between the students' age and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was accepted. The F-ratio was 0.965 ($\alpha = 0.33$).

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 4.47 ($\alpha = 0.03$). The proportion of explained variance was 0.8%.

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 0.817 ($\alpha = 0.37$).

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 0.208 ($\alpha = 0.65$).

The null hypothesis for the problem area skill, Proportional Reasoning, was accepted. The F-ratio was 0.816 ($\alpha = 0.37$).

Hypothesis 1.3a: There is no significant difference between the students' race and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 86.525 ($\alpha = 0.00$). The proportion of explained variance was 17%.

Hypothesis 1.3b: There is no significant difference between the students' race and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 24.740 ($\alpha = 0.00$). The proportion of explained variance was 5.5%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 55.192 ($\alpha = 0.00$). The proportion of explained variance was 11.6%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 47.052 ($\alpha = 0.00$). The proportion of explained variance was 10.5%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 12.991 (α = 0.00). The proportion of explained variance was 2.8%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 68.113 (α = 0.00). The proportion of explained variance was 14%.

Hypothesis 1.4a: There is no significant difference between the students' marital status and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 5.064 (α = 0.02). The proportion of explained variance was 1%.

Hypothesis 1.4b: There is no signficant difference between the students' marital status and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 4.568 (α = 0.03). The proportion of explained variance (adjusted) was 0.9%.

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 0.244 (α = 0.63).

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 9.814 (α = 0.00). The proportion of explained variance was 2.1%.

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 3.199 (α = 0.07).

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 6.797 ($\alpha = 0.01$). The proportion of explained variance was 1.4%.

Hypothesis 1.5a: There is no significant difference between the occupation of the students' fathers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 6.149 ($\alpha = 0.000$). The proportion of explained variance was 7.9%.

Hypothesis 1.5b: There is no significant difference between the occupation of the students' fathers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 2.097 ($\alpha = 0.04$). The proportion of explained variance was 1.8%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 3.474 ($\alpha = 0.00$). The proportion of explained variance was 4%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 4.392 ($\alpha = 0.00$). The proportion of explained variance was 5.4%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 3.474 ($\alpha = 0.00$). The proportion of explained variance was 4%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 2.211 ($\alpha = 0.03$). The proportion of explained variance was 2%.

Hypothesis 1.6a: There is no significant difference between the occupation of the students' mothers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 2.748 ($\alpha = 0.01$). The proportion of explained variance was 2.8%.

Hypothesis 1.6b: There is no significant difference between the occupation of the students' mothers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 2.097 ($\alpha = 0.04$). The proportion of explained variance was 1.8%.

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 1.693 ($\alpha = 0.11$).

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 1.658 ($\alpha = 0.12$).

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 3.826 ($\alpha = 0.00$). The proportion of explained variance was 4.5%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 2.672 ($\alpha = 0.01$). The proportion of explained variance was 2.7%.

Hypothesis 1.7a: There is no significant difference between the level of education of the students' fathers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 4.962 ($\alpha = 0.00$). The proportion of explained variance was 6.2%.

Hypothesis 1.7b: There is no significant difference between the level of education of the students' fathers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 3.55 ($\alpha = 0.00$). The proportion of explained variance was 4.1%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 3.34 ($\alpha = 0.00$). The proportion of explained variance was 3.8%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 2.542 ($\alpha = 0.01$). The proportion of explained variance was 2.5%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 3.230 ($\alpha = 0.00$). The proportion of explained variance was 3.6%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 3.285 ($\alpha = 0.00$). The proportion of explained variance was 3.7%.

Hypothesis 1.8a: There is no significant difference between the level of education of the students' mothers and the students' total score on the IPDT.

This hypothesis was rejected. The F-ratio was 4.187 ($\alpha = 0.00$). The proportion of explained variance was 5.1%.

Hypothesis 1.8b: There is no significant difference between the level of education of the students' mothers and the students' ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 3.891 ($\alpha = 0.01$). The proportion of explained variance was 3.1%.

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 1.699 ($\alpha = 0.11$).

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 0.935 ($\alpha = 0.48$).

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 1.966 ($\alpha = 0.06$).

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 2.211 ($\alpha = 0.03$). The proportion of explained variance was 2%.

Hypothesis 1.9a: There is no significant difference between the students' number of siblings and their total score on the IPDT.

This hypothesis was accepted. The F-ratio was 0.334 ($\alpha = 0.57$).

Hypothesis 1.9b: There is no significant difference between the students' number of siblings and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was accepted. The F-ratio was 0.126 ($\alpha = 0.72$).

The null hypothesis for the problem area skill, Imagery, was accepted. The F-ratio was 1.836 ($\alpha = 0.17$).

The null hypothesis for the problem area skill, Conservation, was accepted. The F-ratio was 0.730 ($\alpha = 0.40$).

The null hypothesis for the problem area skill, Classification, was accepted. The F-ratio was 0.298 ($\alpha = 0.59$).

The null hypothesis for the problem area skill, Proportional Reasoning, was accepted. The F-ratio was 0.293 ($\alpha = 0.60$).

A summary of the statistics of the individual background characteristics related to total score is presented in Table 8. A summary of the statistics of the individual background characteristics related to the five problem area skills is presented in Tables 9 through 13.

After determining those background characteristic variables which are significant, a regression was

Table 8. Summary Statistics of the Individual Background Characteristics as Related to Total Score on the IPDT.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	11.055 (0.00)[b]	0.07	0.16	0.024 (2.4%)
Age	3.224 (0.07)	0.008	0.09	--
Race	86.523 (0.00)	0.17	0.42	0.172 (17.2%)
Marital Status	5.064 (0.02)	0.012	0.11	0.01 (1%)
Fathers' Occupation	6.149 (0.00)	0.10	0.31	0.079 (7.9%)
Mothers' Occupation	2.748 (0.01)	0.05	0.21	0.028 (2.8%)
Fathers' Education	4.962 (0.00)	0.08	0.28	0.062 (6.2%)
Mothers' Education	4.187 (0.00)	0.07	0.26	0.051 (5.1%)
Number of Siblings	0.334 (0.57)	0.001	0.0285	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 9. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Relations.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	0.985 (0.32)[b]	-0.05	0.05	--
Age	0.965 (0.33)	0.05	0.05	--
Race	24.74 (0.00)	-0.24	0.24	0.055 (5.5%)
Marital Status	4.568 (0.03)	0.10	0.10	0.01 (1%)
Fathers' Occupation	3.453 (0.00)	0.06	0.24	0.039 (3.9%)
Mothers' Occupation	2.097 (0.04)	0.03	0.19	0.018 (1.8%)
Fathers' Education	2.891 (0.01)	0.06	0.24	0.041 (4.1%)
Mothers' Education	3.555 (0.00)	0.05	0.22	0.031 (3.1%)
Number of Siblings	0.126 (0.72)	-0.02	0.02	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 10. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Imagery.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	12.159 (0.00)[b]	-0.17	0.17	0.026 (2.6%)
Age	4.470 (0.03)	0.10	0.10	0.09 (0.9%)
Race	55.192 (0.00)	-0.34	0.34	0.116 (11.6%)
Marital Status	0.244 (0.63)	0.02	0.02	--
Fathers' Occupation	3.474 (0.00)	0.06	0.24	0.04 (4%)
Mothers' Occupation	1.693 (0.11)	0.03	0.17	0.01 (1%)
Fathers' Education	3.340 (0.00)	0.05	0.23	0.038 (3.8%)
Mothers' Education	1.699 (0.11)	0.03	0.17	0.012 (1.2%)
Number of Siblings	1.836 (0.17)	0.07	0.07	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 11. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Conservation.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	6.080 (0.01)[b]	-0.12	0.12	0.012 (1.2%)
Age	0.817 (0.37)	-0.04	0.04	--
Race	47.052 (0.00)	-0.32	0.32	0.10 (10%)
Marital Status	9.814 (0.00)	0.15	0.15	0.021 (2.1%)
Fathers' Occupation	4.392 (0.00)	0.07	0.26	0.05 (5%)
Mothers' Occupation	1.658 (0.12)	0.03	0.17	0.01 (1%)
Fathers' Education	2.542 (0.01)	0.04	0.20	0.025 (2.5%)
Mothers' Education	0.935 (0.48)	0.02	0.13	--
Number of Siblings	0.730 (0.40)	0.04	0.04	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 12. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Classification.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	1.450 (0.23)[b]	-0.06	0.06	--
Age	0.208 (0.65)	0.02	0.02	--
Race	12.991 (0.00)	-0.17	0.17	0.028 (2.8%)
Marital Status	3.199 (0.07)	0.09	0.09	--
Fathers' Occupation	3.474 (0.00)	0.06	0.24	0.04 (4%)
Mothers' Occupation	3.826 (0.00)	0.06	0.25	0.045 (4.5%)
Fathers' Education	3.230 (0.00)	0.05	0.23	0.036 (3.6%)
Mothers' Education	1.966 (0.06)	0.03	0.18	0.016 (1.6%)
Number of Siblings	0.298 (0.59)	-0.03	0.03	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 13. Summary Statistics of the Individual Background Characteristics as Related to the Problem Area Skill, Proportional Reasoning.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	23.188 (0.00)[b]	-0.23	0.23	0.05 (5%)
Age	0.816 (0.37)	0.04	0.04	--
Race	68.113 (0.00)	-0.38	0.38	0.14 (14%)
Marital Status	6.797 (0.01)	0.13	0.13	0.138 (13.8%)
Fathers' Occupation	4.818 (0.00)	0.08	0.28	0.06 (6%)
Mothers' Occupation	2.672 (0.01)	0.04	0.21	0.027 (2.7%)
Fathers' Education	3.285 (0.00)	0.05	0.23	0.037 (3.7%)
Mothers' Education	2.211 (0.03)	0.04	0.04	0.02 (2%)
Number of Siblings	0.293 (0.60)	0.03	0.19	--

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

calculated to analyze their effect on the total IPDT score and each problem area skill.

Hypothesis 1.10a: There is no significant difference between the students' background characteristics and their total score on the IPDT.

This hypothesis was rejected. The F-ratio is 5.055 ($\alpha = 0.00$). The proportion of explained variance was 26%.

Hypothesis 1.10b: There is no significant difference between the students' background characteristics and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 2.115 ($\alpha = 0.00$). The proportion of explained variance was 7.4%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 6.011 ($\alpha = 0.00$). The proportion of explained variance was 16.1%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 5.774 ($\alpha = 0.00$). The proportion of explained variance was 15.5%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 2.848 ($\alpha = 0.00$). The proportion of explained variance was 8.9%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 4.923 ($\alpha = 0.00$). The proportion of explained variance was 22.5%.

A summary of the statistics of the combined background characteristics related to the total score is presented in Table 14. A summary of the statistics of the combined background characteristics related to the five problem area skills is presented in Table 14.

Research Hypothesis Two.

A positive, direct relationship exists between the students' background characteristics and their achievement in science education.

Hypothesis 2.1: There is no significant relationship between the students' sex and their achievement in science education.

This hypothesis was accepted. The F-ratio for the regression was 0.206 ($\alpha = 0.65$).

Hypothesis 2.2: There is no significant difference between the students' age and their achievement in science education.

This hypothesis was accepted. The F-ratio for the regression was 1.218 ($\alpha = 0.2$).

Hypothesis 2.3: There is no significant difference between the students' race and their achievement in science education.

Table 14. Summary Statistics of the Combined Background Characteristics as Related to Total Score on the IPDT and the Five Problem Area Skills.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Total Score on the IPDT	5.055 (0.00)[b]	0.32	0.56	0.256 (25.6%)
Relations	2.115 (0.00)	0.14	0.37	0.074 (7.4%)
Imagery	6.011 (0.00)	0.19	0.44	0.16 (16%)
Conservation	5.774 (0.00)	0.19	0.43	0.15 (15%)
Classification	2.848 (0.00)	0.14	0.37	0.09 (9%)
Proportional Reasoning	4.923 (0.00)	0.28	0.53	0.225 (22.5%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

This hypothesis was rejected. The F-ratio for the regression was 33.149 ($\alpha = 0.00$). The proportion of explained variance was 7%.

Hypothesis 2.4: There is no significance between the students' marital status and their achievement in science education.

This hypothesis was rejected. The F-ratio for the regression was 7.771 ($\alpha = 0.01$). The proportion of explained variance was 1.6%.

Hypothesis 2.5: There is no significant difference between the occupation of the students' fathers and the students' achievement in science education.

This hypothesis was accepted. The F-ratio was 1.271 ($\alpha = 0.26$).

Hypothesis 2.6: There is no significant difference between the occupation of the students' mothers and the students' achievement in science education.

This hypothesis was rejected. The F-ratio was 2.632 ($\alpha = 0.01$). The proportion of explained variance was 2.7%.

Hypothesis 2.7: There is no significant difference between the level of education of the students' fathers and the students' achievement in science education.

This hypothesis was rejected. The F-ratio was 2.154 ($\alpha = 0.04$). The proportion of explained variance was 1.9%.

Hypothesis 2.8: There is no significant difference between the level of education of the students' mothers and the students' achievement in science education.

This hypothesis was accepted. The F-ratio was 1.706 (α = 0.11).

Hypothesis 2.9: There is no significant difference between the students' number of siblings and their achievement in science education.

This hypothesis was rejected. The F-ratio was 7.287 (α = 0.01). The proportion of explained variance was 1.5%.

A summary of the statistics of the individual background characteristics related to achievement in science education is presented in Table 15.

After determining those background characteristic variables which are significant, a regression was calculated to analyze their effect on achievement in science education.

Hypothesis 2.10: There is no significant difference between the students' background characteristics and their achievement in science education.

This hypothesis was rejected. The F-ratio was 3.613 (α = 0.00). The proportion of explained variance was 9.6%.

A summary of the statistics of the combined background characteristics related to achievement in science education is presented in Table 16.

Table 15. Summary Statistics of the Individual Background Characteristics as Related to Achievement in Science Education.

Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Sex	0.206 (0.65)[b]	-0.02	0.02	--
Age	1.218 (0.2)	0.05	0.05	--
Race	33.149 (0.00)	0.27	0.27	0.07 (7%)
Marital Status	7.771 (0.01)	-0.14	0.14	0.02 (2%)
Fathers' Occupation	1.271 (0.26)	0.02	0.15	--
Mothers' Occupation	2.632 (0.01)	0.04	0.21	0.027 (2.7%)
Fathers' Education	2.154 (0.04)	0.04	0.19	0.02 (2%)
Mothers' Education	1.706 (0.11)	0.03	0.17	0.01 (1%)
Number of Siblings	7.287 (0.01)	-0.13	0.13	0.015 (1.5%)

[a] R^2 is the proportion of variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 16. Summary Statistics of the Combined Background Characteristics as Related to Achievement in Science Education.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Achievement in Science Education	3.613 (0.00)[b]	0.13	0.36	0.096 (9.6%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Analyses of Reading and Math Ability.

Research Hypothesis Three.

A positive and direct relationship exists between the students' reading and math ability and the cognitive skills the students have attained.

Hypothesis 3.1a: There is no significant difference between the students' reading ability and their total score on the 1PDT.

This hypothesis was rejected. The F-ratio was 204.62 ($\alpha = 0.00$). The proportion of explained variance was 33%.

Hypothesis 3.1b: There is no significant difference between the students' reading ability and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 63.831 ($\alpha = 0.00$). The proportion of explained variance was 13.2%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 93.258 ($\alpha = 0.00$). The proportion of explained variance was 18%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 102.849 ($\alpha = 0.00$). The proportion of explained variance was 19.6%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 121.033 (α = 0.00). The proportion of explained variance was 22%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 67.44 (α = 0.00). The proportion of explained variance was 13.9%.

Hypothesis 3.2a: There is no significant difference between the students' math ability and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 212.35 (α = 0.00). The proportion of explained variance was 33.7%.

Hypothesis 3.2b: There is no significant difference between the students' math ability and their ability in each of the five problem area skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 55.11 (α = 0.00). The proportion of explained variance was 11.4%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 117.935 (α = 0.00). The proportion of explained variance was 21.8%.

The null hypothesis for the problem area skill, Conservation, was rejected. The F-ratio was 69.603 (α = 0.00). The proportion of explained variance was 14%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 47.572 (α = 0.00). The proportion of variance explained was 10%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 114.479 (α = 0.00). The proportion of explained variance was 21.3%.

Hypothesis 3.3a: There is no significant difference between the linear additive effects of the students' reading and math ability and their total score on the IPDT.

This hypothesis was rejected. The F-ratio was 141.782 (α = 0.00). The proportion of explained variance was 40%.

Hypothesis 3.3b: There is no significant difference between the linear additive effect of the students' reading and math ability and their ability in each of the five problem skills.

The null hypothesis for the problem area skill, Relations, was rejected. The F-ratio was 38.465 (α = 0.00). The proportion of explained variance was 15.2%.

The null hypothesis for the problem area skill, Imagery, was rejected. The F-ratio was 68.439 (α = 0.00). The proportion of explained variance was 24.4%.

The null hypothesis for the problem skill, Conservation, was rejected. The F-ratio was 46.720 (α = 0.00). The proportion of explained variance was 18%.

The null hypothesis for the problem area skill, Classification, was rejected. The F-ratio was 29.715 (α = 0.00). The proportion of explained variance was 12%.

The null hypothesis for the problem area skill, Proportional Reasoning, was rejected. The F-ratio was 61.330 (α = 0.00). The proportion of explained variance was 22.4%.

A summary of the statistics of reading and math ability related to total score on the IPDT and the five problem area skills is presented in Table 17.

Research Hypothesis Four.

A positive and direct relationship exists between the students' reading and math ability and their achievement in science education.

Hypothesis 4.1: There is no significant difference between the students' reading ability and their achievement in science education.

This hypothesis was rejected. The F-ratio was 74.104 (α = 0.00). The proportion of explained variance was 15%.

Hypothesis 4.2: There is no significant difference between the students' math ability and their achievement in science education.

This hypothesis was rejected. The F-ratio was 61.995 (α = 0.00). The proportion of explained variance was 12.7%.

Table 17. Summary Statistics of the Reading and Math Ability as Related to Total Score and the Five Problem Area Skills.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Total Score on the IPDT	141.782 (0.00)[b]	0.41	0.63	0.40 (40%)
Relations	38.465 (0.00)	0.16	0.40	0.15 (15%)
Imagery	68.439 (0.00)	0.25	0.50	0.244 (24.4%)
Conservation	46.720 (0.00)	0.18	0.43	0.18 (18%)
Classification	29.715 (0.00)	0.13	0.35	0.12 (12%)
Proportional Reasoning	61.330 (0.00)	0.23	0.48	0.22 (22%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Hypothesis 4.3: There is no significant difference between the linear additive effects of the students' reading and math ability and their achievement in science education.

This hypothesis was rejected. The F-ratio was 43.809 ($\alpha = 0.00$). The proportion of explained variance was 17%.

A summary of the statistics of reading and math ability related to achievement in science education is presented in Table 18.

Analysis of Cognitive Ability and Achievement in Science Education.

Research Hypothesis Five.

A positive and direct relationship exists between the students' cognitive abilities and their achievement in science education.

Hypothesis 5: There is no significant difference between the students' total score on the IPDT and their achievement in science education.

This hypothesis was rejected. The F-ratio was 62.714 ($\alpha = 0.00$). The proportion of explained variance was 12.8%.

A summary of the statistics of cognitive development as related to achievement in science education is presented in Table 19.

Table 18. Summary Statistics of the Reading and Math Ability as Related to Achievement in Science Education.

	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Achievement in Science Education	43.809 (0.00)[b]	0.17	0.42	0.17 (17%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Table 19. Summary Statistics of Cognitive Development as Related to Achievement in Science Education.

	Cognitive Development			
	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Achievement in Science Education	62.714 (0.00)[b]	0.35	0.36	0.128 (12.8%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Analysis in Background Characteristics, Cognitive Development and Achievement in Science Education.

Research Hypothesis Six.

A positive and direct relationship exists between the students' background characteristics, their cognitive development and their achievement in science education.

Hypothesis 6: There is no significant difference between the linear, additive effects of the students' background characteristics, their cognitive development and their achievement in science education.

This hypothesis was rejected. The F-ratio was 5.792 ($\alpha = 0.00$). The proportion of explained variance was 17%.

A summary of the statistics of the combined effects of background characteristics and cognitive development as related to achievement in science education is presented in Table 20.

Analysis of Reading and Math Ability, Cognitive Development and Achievement in Science Education.

Research Hypothesis Seven.

A positive and direct relationship exists between the students' reading and math ability, their cognitive development and their achievement in science education.

Table 20. Summary of the Multivariate Statistics of the Combined Background Characteristics, Reading and Math Ability and Cognitive Development as Related to Achievement in Science Education.

	Achievement in Science Education			
Variable	F-Ratio	Beta	R	R^2 (Adjusted)[a]
Combined Background Characteristics and Cognitive Development	5.792 (0.00)[b]	0.21	0.45	0.17 (17%)
Reading, Math Ability and Cognitive Development	32.762 (0.00)	0.19	0.44	0.186 (18.6%)
Combined Background Characteristics, Reading and Math Ability and Cognitive Development	6.753 (0.00)	0.25	0.50	0.22 (22%)

[a] R^2 is the proportion of the variance of the dependent variable explained by the independent variable.

[b] Level of probability.

Hypothesis 7: There is no significant difference between the linear, additive effects of the students' reading and math ability, their cognitive development and their achievement in science education.

This hypothesis was rejected. The F-ratio was 32.762 ($\alpha = 0.00$). The proportion of explained variance was 18.6%.

A summary of the statistics of the combined effects of reading and math ability and cognitive development as related to achievement in science education is presented in Table 20.

Analysis of All Variables and Achievement in Science Education.

Research Hypothesis Eight.

A positive, direct additive linear relationship exists between the students' background characteristics, reading and math abilities, total score on the IPDT and their achievement in science education.

Hypothesis 8: There is no significant difference between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

This hypothesis was rejected. The F-ratio was 6.753 ($\alpha =0.00$). The proportion of explained variance was 22%.

A summary of the statistics of the combined effects of background characteristics, reading and math ability and cognitive development as related to achievement in science education is presented in Table 20.

Analysis of Cognitive Development as an Intervening Variable.

Research Hypothesis Nine.

Cognitive development is a mediating variable between the independent variables, background characteristics, reading ability, math ability and the dependent variable, achievement in science education.

Hypothesis 9a: There is a direct effect of cognitive development on achievement in science education independent of the overlapping effects of background characteristics, reading ability and math ability.

Hypothesis 9b: There are direct effects on the background characteristics, reading ability and math ability on achievement in science education.

Hypothesis 9c: There are indirect effects of background characteristics, reading ability, and math ability on achievement in science education mediated by cognitive development.

In order to determine the direct effect of cognitive development independent of the indirect effects of background characteristics, reading ability and math ability and the total indirect effects of background characteristics, reading ability and math ability, a different statistical technique, path analysis, was used.

> "Path analysis is not a method of discovering causes, but a method applied to a causal model formulated by the researcher on the basis of knowledge and theoretical considerations (Kerlinger, 1973:305)."

> "Path analysis techniques attempt to estimate the magnitude of causal 'pathways.' The causal sequence whose paths are to be estimated is specified by theoretical or hypothesis-testing considerations. Estimates of paths are arrived at by series of ordinary least square regressions, each dependent variable being regressed upon all other variables presumed to cause it (Futterman, 1980:33)."

According to Kerlinger (1973:310), "A path coefficient indicates the direct effect of a variable taken as a cause of a variable taken as an effect." The symbol for a path coefficient is a p with two subscripts. The first subscript indicates the dependent variable. The second subscript indicates the independent variable (see Figure 5).

A variable whose causes are determined by factors not under consideration in the model is an exogenous variable. No explanation of the variability of exogenous variables is given in the model. In Figure 4, Background Characteristics is an exogenous variable.

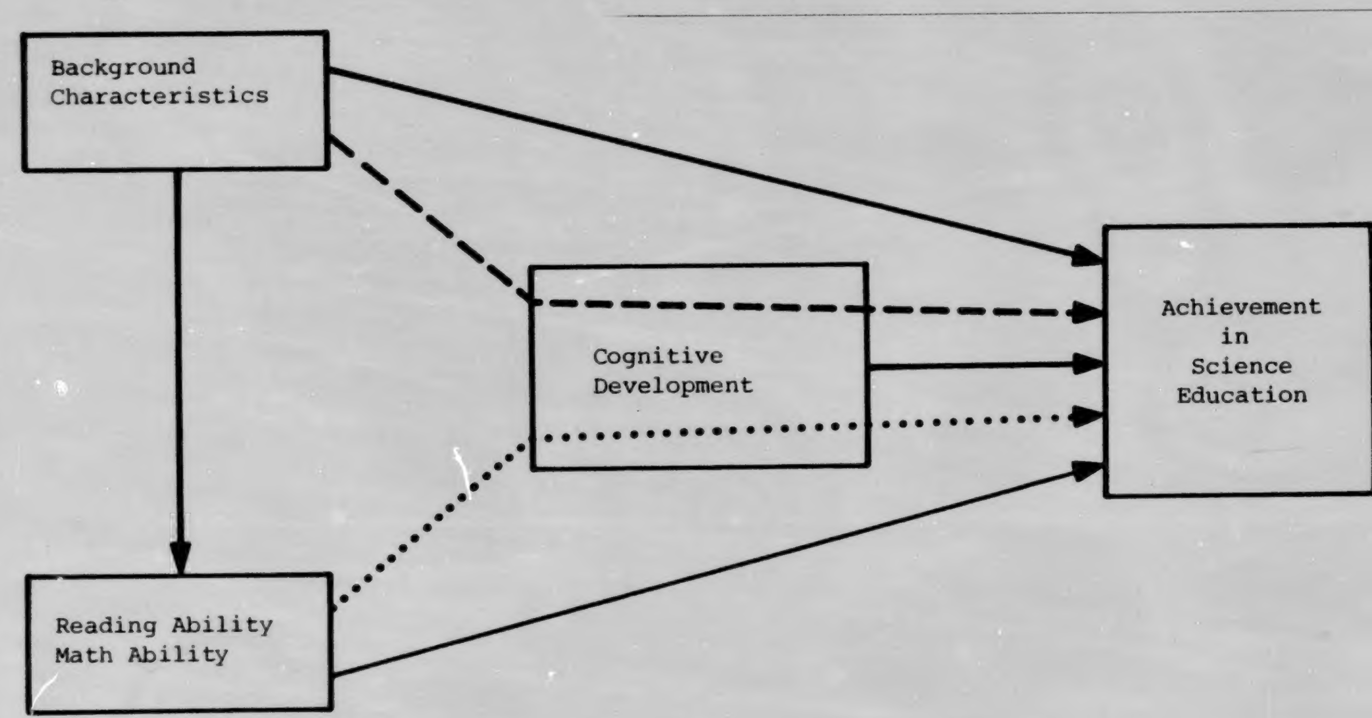

Background Characteristics
Cognitive Development
Achievement in Science Education
Reading Ability
Math Ability

Figure 4. Paradigm.

The remaining variables are endogenous variables. The variance of endogenous variables is assumed to be completely explained by exogenous and endogenous variables in the system. In Figure 4, Reading Ability and Math Ability, Cognitive Development and Achievement in Science Education are endogenous variables. An endogenous variable such as Cognitive Development can be treated as a dependent variable in relation to Background Characteristics and Reading and Math Ability. Cognitive Development can also be treated as an independent variable in relation to Achievement in Science Education.

Each dependent variable can be represented by an equation which consists of the variables upon which the dependent variable is assumed to be dependent and a term representing all other factors not under consideration in the model (residuals). "It is convenient not to represent residuals in the diagrams (Kerlinger, 1973:309)." The residuals are presented in Table 21.

Within the model, the correlations between two variables can be decomposed into that part of the correlation which is due to the direct effect of a cause and that part of the correlation which is due to the indirect effect of a cause. For example, the causal equation for the total effect of the variable, race, on achievement in science education is: $r_{15} = p_{15} + p_{12}r_{25} + p_{13}r_{35} + p_{14}r_{45} + p_{16}r_{56} + p_{17}r_{57} + p_{18}r_{58}$. The direct effect of

Table 21. Path Analysis Residuals

Variable	Residuals[a]
Reading Ability	0.87
Math Ability	0.88
Cognitive Development	0.75
Achievement in Science Education	0.89

[a] The formula for calculating the residuals is $\sqrt{1 - R^2}$.

race on achievement in science education is p_{15}. The other causal paths are the indirect effects.

The paradigm previously presented is a simplified paradigm (Figure 4). However, the box representing the term, background characteristics, is, in reality, a composite of all the background characteristics whose null hypotheses were rejected - race, mothers' occupation, fathers' education and number of siblings. The box representing reading and math ability is, in reality, a composite of reading ability and math ability. Figure 5 was the paradigm used for the path analysis.

Solutions for the direct effect and the total indirect effects of a variable such as cognitive development on another variable such as achievement in science education were accomplished in two steps. Step One calculates the direct effect and Step Two calculates the Total Indirect Effects (TIE).

The direct effect was determined from the beta of each variable in the multiple regression equation of achievement in science education. "It is customary to use the standardized betas as the path coefficients (Land, 1969)."

The betas obtained by the multiple linear regression were partial betas. A partial beta is a beta of one variable in an equation with all the other variables in the equation held constant. This beta is then the path

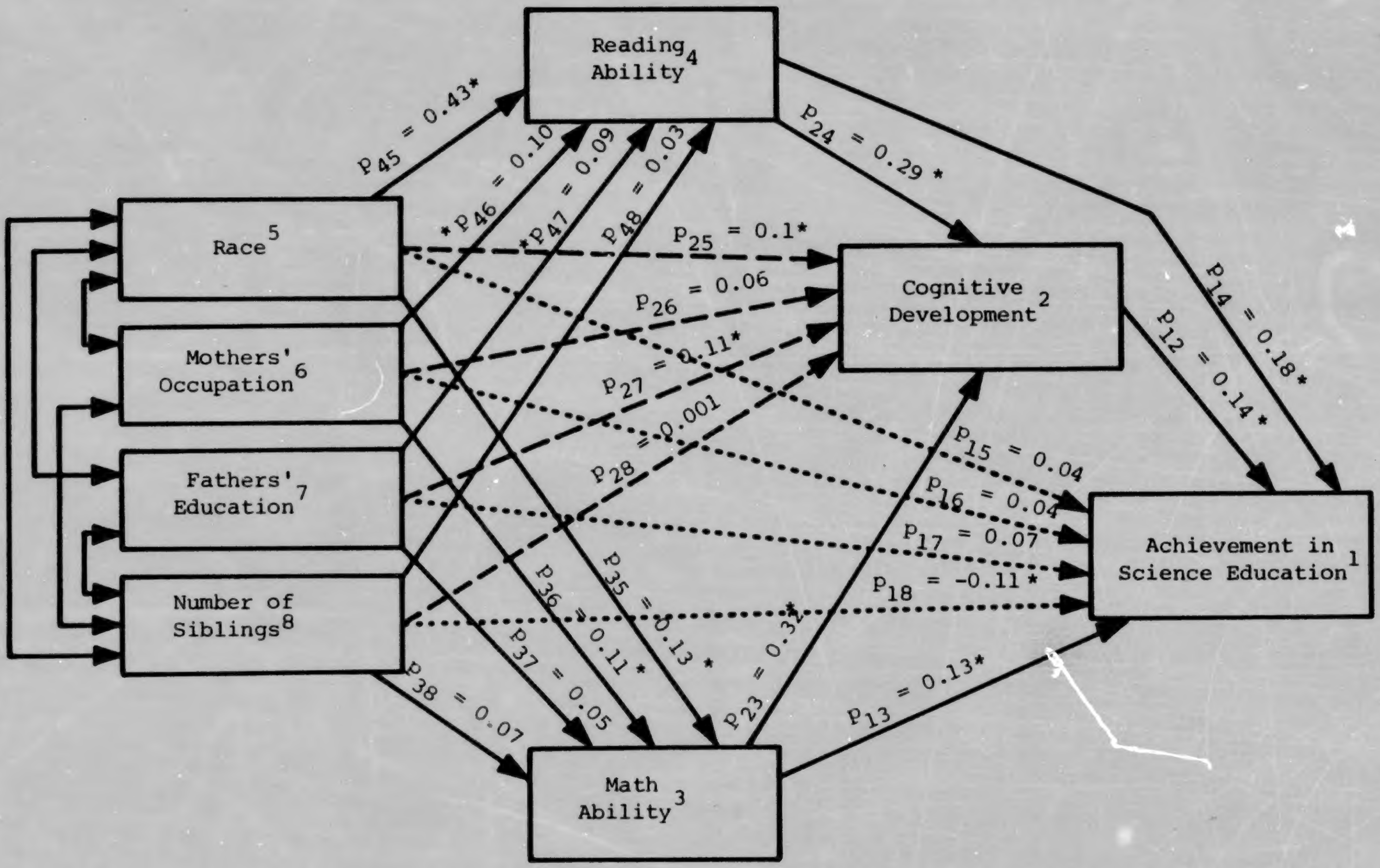

Reading Ability$_4$
Race^5
Mothers' Occupation^6
Fathers' Education^7
Number of Siblings^8
Cognitive Development^2
Achievement in Science Education^1
Math Ability^3
$P_{45} = 0.43*$
$*P_{46} = 0.10$
$*P_{47} = 0.09$
$P_{48} = 0.03$
$P_{24} = 0.29*$
$P_{25} = 0.1*$
$P_{26} = 0.06$
$P_{27} = 0.11*$
$P_{28} = 0.001$
$P_{14} = 0.18*$
$P_{12} = 0.14*$
$P_{15} = 0.04$
$P_{16} = 0.04$
$P_{17} = 0.07$
$P_{18} = -0.11*$
$P_{36} = 0.11*$
$P_{35} = 0.13*$
$P_{37} = 0.05$
$P_{38} = 0.07$
$P_{23} = 0.32*$
$P_{13} = 0.13*$

Figure 5. Path Analysis Paradigm.

coefficient which is equal to the direct effect of that variable on the dependent variable.

The betas from the multiple linear regression of race, mothers' occupation, fathers' education, number of siblings, reading ability, math ability and cognitive development on achievement in science education are presented in Table 22.

Therefore, the direct effect of cognitive development on achievement in science education is 0.14. The direct effect of math ability on achievement in science education is 0.13. The direct effect of reading ability on achievement in science education is 0.18. The direct effect of the background characteristics on achievement in science education are:

Background Variable	Direct Effect
Race	0.04
Mothers' Occupation	0.04
Fathers' Education	0.07
Number of Siblings	-0.11

Figure 5 shows the path analysis paradigm with all the path coefficients. The path coefficients not considered in this research study are shown in the path analysis for clarification of the entire analysis. These path coefficients were obtained from the appropriate multiple regression equations.

Table 22. Partial Betas of Achievement in Science Education.

Variable	Beta	Path Coefficient
Race	0.04069	0.04
Mothers' Occupation	0.03704	0.04
Fathers' Education	0.06855	0.07
Number of Siblings	-0.10881	-0.11
Reading Ability	0.18140	0.18
Math Ability	0.13177	0.13
Cognitive Development	0.13951	0.14

In the second step which determined the Total Indirect Effects, (TIE), of a variable, "all that is necessary is to subtract the direct effect from the correlation coefficient between it and the dependent variable (Kerlinger, 1973: 317)."

Therefore, to determine the total indirect effects of cognitive development, the direct effect of cognitive development (0.14) is subtracted from the correlation coefficient (0.36). The correlation coefficient of cognitive development and achievement in science education is shown in the correlation matrix as presented in Table 23. The TIE of background characteristics and reading and math ability is:

$$\begin{aligned} \text{TIE} &= 0.36 - 0.14 \\ &= 0.22 \end{aligned}$$

The indirect effect of cognitive development on achievement in science education (0.22) are spurious effects because they are a consequence of the variables, cognitive development, reading ability and math ability having a common cause, the background characteristics. Though 0.22 is a spurious indirect effect, the other variables do have legitimate indirect effects on achievement in science education operating through cognitive development.

The indirect effect of reading ability on achievement in science education through cognitive development

Table 23. Correlation Matrix.

	Race	Mothers' Occupation	Fathers' Education	Number of Siblings	Reading Ability	Math Ability	Cognitiv Developme
Mothers' Occupation	-0.0762						
Fathers' Education	-0.1242	0.2452	-0.1292				
Number of Siblings	0.0055	-0.1030	-0.1292				
Reading Ability	-0.1120	0.1950	0.2109	-0.0234			
Math Ability	-0.0760	0.1956	0.1800	-0.0250	0.6356		
Cognitive Development	-0.1222	0.2274	0.2728	-0.0687	0.5737	0.5804	
Achievement	-0.0679	0.1621	0.1950	-0.0922	0.3884	0.3594	0.3612

can be obtained from the path coefficients $p_{24}p_{12}$ (p_{12} = 0.14, p_{24} = 0.29). The indirect effect is 0.04.

The indirect effect of math ability on achievement in science education through cognitive development can be determined from the path coefficients, $p_{23}p_{12}$ (p_{12} = 0.4, p_{23} = 0.32). The indirect effect is 0.05.

The indirect effect of race on achievement in science education through cognitive development is $p_{25}p_{12}$ = 0.014. The indirect effect of mothers' occupation on achievement in science education through cognitive development is $p_{26}p_{12}$ = 0.008. The indirect effect of fathers' education on achievement in science education mediated by cognitive development is $p_{27}p_{12}$ = 0.02. The indirect effect of number of siblings on achievement in science education mediated by cognitive development is $p_{26}p_{12}$ = 0.0001.

As can be seen from Figure 5, many path coefficients, such as race, mothers' occupation and fathers' education to achievement in science education, are small and insignificant. (The path coefficients in Figure 5 which are significant are indicated with an *.) If these insignificant paths were eliminated, the path analysis mode would be a more parasimonious model.

Summary.

This chapter showed the relationships between the General Biology students' background characteristics, their reading and math ability and their cognitive development level to their achievement in science education using multiple regression. Path analysis was used to show that cognitive development was a mediating variable between background characteristics and reading and math ability. The summary, conclusions, discussion and recommendations of this study are presented in Chapter V.

CHAPTER V

SUMMARY, CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

Summary.

This research study was undertaken to identify the background characteristics of students enrolled in a General Biology course at WC_3. It was designed to formulate a predictive equation which could be utilized to identify those students who most probably would not succeed in science education at a large, urban community college.

The purposes of this study were to:

(1) Examine and analyze the students' background characteristics and their reading and math abilities as they relate to the students' cognitive development.

(2) Examine and analyze the students' background characteristics and their reading and math ability as they relate to the students' achievement in science education.

(3) Examine and analyze the students' cognitive development as it acts as a mediating variable between the students' background characteristics, and their reading and math ability with their achievement in science education.

(4) Establish a predictive equation to identify students who may not succeed in science education.

Data were collected on 420 students in the WC_3 regional system. Instruments used were:

(1) The College Biology Student Survey.

(2) The Inventory of Piaget's Developmental Tasks (IPDT).

(3) The CGP Applied Arithmetic Placement Test (CGP).

(4) The Nelson Denny Reading Test, Form F.

(5) Achievement in science education was determined by the letter grade assigned by the instructors.

These instruments were administered by this researcher to General Biology students during the Fall Semester, 1981. The data collected were used in the statistical analyses.

Data Analysis.

The descriptive statistics showed that the WC_3 General Biology student classes were racially balanced, 49% white and 51% non-white. The median age was 26. Females comprised 82% of the sample. Seventy-one percent of the students were single, divorced, separated or widowed while 29% were married. From an 80% response rate of students who knew their parents' occupation, 45% of the fathers had a blue collar job; 35% had a white collar job. Approximately 50% of the mothers worked full or part-time, the majority had service related or clerical jobs. From an 85%

response rate of students who knew their parents' level of formal education, 34% of the parents did not finish high school, 27% of the mothers and 19% of the fathers graduated from high school, 23% of the fathers and 26% of the mothers had formal schooling beyond high school either in a technical school, community college, college or university. The students had a twelfth grade reading level. The average score on the CGP was 15 correct answers out of a possible 25 correct answers. The average score on the IPDT was 49 correct items out of a possible 72 correct choices. Only 68% of these items were answered correctly. The students' average grade was 2.7 (C+).

Simple regressions were calculated on each of the background characteristics, sex, age, race, marital status, parents' occupation, parents' education, and number of siblings with the students' total score on the IPDT, each of the five problem area skills identified in the IPDT (see Chapter I), and the students' achievement in science education. Only those background characteristics whose null hypotheses were rejected were used in the multiple linear regressions.

Null hypotheses were constructed for the first eight research hypotheses. The α was set at 0.05. Multiple linear regressions were computed to test these hypotheses.

Research Hypothesis One: A positive and direct relationship exists between the students' background characteristics and the cognitive skills that students have attained.

> Hypothesis 1a: There is no significant difference between the students' background characteristics and the total score on the IPDT.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The variables, sex, race, marital status, fathers' occupation and parents' education accounted for 25.6% of the variance of cognitive development. The F-ratio was 5.055 ($\alpha = 0.00$).

> Hypothesis 1b: There is no significant difference between the students' background characteristics and their ability in each of the five problem area skills.

The null hypothesis was rejected indicating that the research hypothesis was accepted. This researcher ranked the five problem area skills from those skills showing the highest variance attributed to background characteristics to those skills showing the least variance:

F-ratio ($\alpha = 0.00$)

1.	Proportional Reasoning	4.923	22.5% variance
2.	Imagery	6.011	16% variance
3.	Conservation	5.774	15% variance
4.	Classification	2.848	9% variance
5.	Relations	2.115	7.4% variance

Research Hypothesis Two: A positive and direct relationship exists between the students' background characteristics and their achievement in science education.

> Hypothesis 2: A positive and direct relationship exists between the students' background characteristics and their achievement in science education.

The null hypothesis was rejected indicating the research hypothesis was accepted. The background characteristics, marital status, race, fathers' education, mothers' occupation and number of siblings accounted for 9.6% of the variance of achievement in science education. The F-ratio was 3.613 ($\alpha = 0.00$).

Research Hypothesis Three: A positive and direct relationship exists between the students' reading and math ability and the cognitive skills the students have attained.

Hypothesis 3a: There is no significant difference between the linear additive effects of the students' reading and math ability and their total score on the IPDT.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 141.782 ($\alpha = 0.00$). Reading and math ability explained 40% of the variance of the total score of the IPDT.

Hypothesis 3b: There is no significant difference between the linear additive effect of the students' reading and math ability and their ability in each of the five problem area skills.

The null hypothesis was rejected indicating that the research hypothesis was accepted. This researcher ranked the five problem area skills from those skills showing the highest variance attributed to reading and math ability to those skills showing the least variance:

F-ratio ($\alpha = 0.00$)

1.	Imagery	68.439	24.4% variance
2.	Proportional Reasoning	61.330	22% variance
3.	Conservation	46.720	18% variance
4.	Relations	38.465	15% variance
5.	Classification	29.715	12% variance

Research Hypothesis Four: A positive and direct relationship exists between the students' reading and math ability and their achievement in science education.

> Hypothesis 4: There is no significant difference between the students' reading and math ability and their achievement in science education.

The null hypothesis was rejected indicating the research hypothesis was accepted. The F-ratio was 43.809 ($\alpha = 0.00$). Reading and math ability explained 17% of the variance of achievement in science education.

Research Hypothesis Five: A positive and direct relationship exists between the students' cognitive skills and their achievement in science education.

> Hypothesis 5: There is no significant difference between the students' total score on the IPDT and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 6.2714 ($\alpha = 0.00$). Cognitive development as measured by the IPDT explained 12.8% of the variance of achievement in science education.

Research Hypothesis Six: A positive and direct relationship exists between the students' background characteristics, their cognitive development and their achievement in science education.

> Hypothesis 6: There is no significant difference between the linear, additive effects of the students' background characteristics, their cognitive development and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 5.792 ($\alpha = 0.00$). The linear additive effect of background characteristics and cognitive development explained 17% of the variance of achievement in science education.

Research Hypothesis Seven: A positive and direct relationship exists between the students' reading and math ability, their cognitive development and their achievement in science education.

> Hypothesis 7: There is no significant difference between the linear, additive effects of the students' reading and math ability, their cognitive development and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 32.762 (α = 0.00). The linear additive effect of background characteristics, reading and math ability and cognitive development explained 18.6% of the variance of achievement in science education.

Research Hypothesis Eight: A positive, direct additive linear relationship exists between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

> Hypothesis 8: There is no significant difference between the students' background characteristics, reading and math ability, total score on the IPDT and their achievement in science education.

The null hypothesis was rejected indicating that the research hypothesis was accepted. The F-ratio was 6.753 (α = 0.00). The linear additive effect of background characteristics, reading and math ability and total score on the IPDT explained 22% of the variance of achievement in science education.

Research Hypothesis Nine was examined using path analysis. Path analysis is a statistical technique used to "determine whether or not a pattern of correlations for a set of observations is consistent with a specific theoretical formulation (Kerlinger, 1973:317)."

Research Hypothesis Nine: Cognitive development is a mediating variable between the independent variables, background characteristics, reading and math ability and the dependent variable, achievement in science education.

> Hypothesis 9a: There is a direct effect of cognitive development on achievement in science education independent of the overlapping effects of background characteristics, reading and math ability.
>
> The direct effect of cognitive development established by the path coefficient was 0.14.
>
> Hypothesis 9b: There are direct effects of background characteristics, reading ability and math ability on achievement in science education.
>
> The direct effects of the background characteristics on achievement in science education were: race - 0.04, mothers' occupation - 0.04, fathers' education - 0.07, and number of siblings - -0.11. The direct effects of reading ability on achievement in science education was

0.18. The direct effect of math ability on achievement in science education was 0.13.

Hypothesis 9c: There are indirect effects on the background characteristics, reading ability and math ability on achievement in science education mediated by cognitive development.

The indirect effects of background characteristics on achievement in science education mediated by cognitive development were: race - 0.014, mothers' occupation - 0.008, fathers' education - 0.02, and number of siblings - 0.0001. The indirect effect of reading ability on achievement in science education mediated by cognitive development was 0.04. The indirect effect of math ability on achievement in science education mediated by cognitive development was 0.05.

Conclusions.

The following conclusions were made while recognizing the limitations of the study.

The demographic data obtained from the test instruments showed that the General Biology classes had a higher percentage of females (82%) than males (18%). The students' median age was 26. The classes were racially balanced (49% white, 51% non-white). The majority of the students (71%) were single or formerly married. From an 85% response rate of students who knew their parents' level of formal education, 34% of the parents did not finish high school, 27% of the mothers and 19% of the fathers graduated from high school and 23% of the fathers and 26% of the mothers had formal schooling beyond high school. Forty-five percent of the fathers were employed in blue collar jobs and 35% had white collar jobs. Of those mothers employed (51%), the majority were in service related or clerical jobs. The average math score of the students was 15 correct answers out of 25 possible choices. The students' average reading ability was twelfth grade. Their average score on the IPDT was 49 correct items out of a possible 72 correct items. Only 9% of the students were at the formal level of cognitive development, while 91% were at the concrete level of cognitive development. The average grade was 2.7 (C+).

The conclusions inferred from the data are summarized according to the purposes of the study.

The background characteristics, reading and math ability are positively related to the students' cognitive development. Knowing the sex, marital status, mothers' occupation, fathers' education, their reading level and their math ability accounted for 42.5% of the variance in the students' cognitive development.

The background characteristics, reading and math ability are positively related to the students' achievement in science education. Knowing the sex, marital status, mothers' occupation, fathers' education, their reading level and their math level accounted for 43% of the variance in the students' achievement in science education.

Cognitive development accounted for 12.8% of the variance in the students' achievement in science education. With cognitive development as a mediating variable, the background characteristics and the students' reading and math ability accounted for 22% of the variance in achievement in science education. An equation which could identify students who may not succeed in science education can be formulated using the following factors: race, mothers' occupation, fathers' education, number of siblings, reading ability, math ability, cognitive development skills and marital status.

$$Y' = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6H_6 + b_7X_7 + b_8X_8$$

If

X_1 = cognitive development
X_2 = reading ability
X_3 = math ability
X_4 = race
X_5 = mothers' occupation
X_6 = fathers' education
X_7 = number of siblings
X_8 = marital status

then with the appropriate b's and the Y-intersect (a) the formula would read:

$$Y' = 0.42 + 0.14X_1 + 0.18X_2 + 0.13X_3 + 0.04X_4$$
$$+ 0.04X_5 + 0.07X_6 + -0.11X_7 + -0.06X_8$$

It must be remembered that this equation is based on group data and predication error for an individual student may be sizable.

Discussion.

Background Characteristics and Cognitive Development. According to the literature, the students' level of cognitive development depends on many factors which can be considered background characteristics: age, sex, race and parental level of education. In this study age had no effect on cognitive development. The null hypothesis was accepted. The fact that 61% of the students are 22 or older may account, in part, for this phenomenon. There could be a leveling effect because the majority of the students are older.

The explained variance attributed to sex ranged from 0% on the problem area skills, Relations and Classification to 5% on the problem area skill, Proportional Reasoning. The amount of variance of the total score explained by sex is 2.4%. Considering the importance it is given in the literature, this variable explains a small amount of the variance. However, 82% of the General Biology students are female. This high ratio of females to males could dampen or level off the effect of sex on the students' cognitive development.

Race accounted for the greatest amount of variance in cognitive development. Forty-nine percent of the students are white, 51% are non-white. In examining the five problem area skills, whites attained more cognitive skills in all five problem area skills.

Background Characteristics and Achievement in Science Education. The background characteristics, race, marital status, mothers' occupation, fathers' education and number of siblings, contributed to the amount of explained variance of achievement in science education.

In the literature, some researchers found no significant relationship between sex and achievement while others found a significant relationship. In this research study, sex was not significantly related to achievement. By examining a bivariate frequency table, the percentage of females to males achieving A's, B's, C's, D's and E's showed only a maximum of 2% difference. Therefore, this researcher would have to conclude that sex was not significantly related to achievement in science education.

Age was not significantly related to achievement in this research study. The literature on achievement in community college found that older, married women achieved higher than any other groupings of students. Due to a higher percentage of older students (61%) in this study, a leveling effect may have occurred.

Race was the background characterisic which explained the greatest amount of the variance (7%) of achievement from all the background characteristics. White students achieved better than non-white students. This researcher found no literature regarding the effect of race on science achievement in community college students. However, the literature on student achievement in community college suggests that race would not be a factor in achievement. This discrepancy between the literature and the research results may be accounted for because WC_3 serves such a range of students and the lower income black students are clustered at two campuses.

This research study agreed with the literature that marital status has a significant relationship to achievement in science education. There was a higher percentage of married students (87%) passing the course than single students (79%).

Cognitive Development, Math Ability and Achievement. The average score of the IPDT was 49. This means that on the average only 68% of the items were answered correctly. Upon examining the five problem area skills, Relations, Imagery, Conservation, Classification and Proportional

Reasoning, 59% of the students have the cognitive skill, Relations; 37% have the cognitive skill, Imagery; 18% have the cognitive skill, Conservation; 9% have the cognitive skill, Classification and 11% have the cognitive skill, Proportional Reasoning.

Few students have all of those cognitive skills and could be classified as being at Piaget's formal level of cognitive development. In fact, the majority of the students have, at best, two of the cognitive skills. The students as a group must be considered to be at the concrete level of cognitive development. These test results agree with the results of other studies. The majority of students (adults) have not reached the formal level of cognitive development.

Those cognitive skills, Conservation, Classification and Proportional Reasoning, which require math ability, have the smallest number of students as having attained these skills (18%, 9%, 11%, respectively). When the students' math ability is examined, only 16% of the students answered 20 or more questions correctly on the CGP. Since the CGP has 25 questions on elementary math, it must be concluded that the WC_3 General Biology students are deficient in math. This math deficiency also affects their cognitive skills. If they cannot use ratios, they cannot reason proportionally.

The lack of math ability can affect their achievement in science education. The General Biology course covers topics such as chemical equations, metrics, and genetic problems, all of which require math ability to understand.

In the past, students have had great difficulty solving genetic problems which are based on ratio and proportions. Their lack of math ability partially explains their inability to solve these problems. Teaching the metric system is a morass into which both teachers and students slowly sink. Lack of math ability directly influences the students' inability to understand the metric system. Consequently, lack of math ability adversely affects the students' cognitive development and achievement in science education.

Achievement.

The number of students (67%) earning a B or better in General Biology seemed high. A number of factors could account for this high rate of achievement. The grades could be inflated since teachers made their own tests and standardized tests were not given. Marginal or failing students may not have participated in the study. Thus, insufficient data from these marginal students could have inflated the grades. The students' reading level may play a more important role than math ability on achievement.

The students had a twelfth grade reading level, but only 16% could correctly answer 20 or more problems correctly out of 25 possible choices on a math test approximately sixth grade level. Conversely, math ability played a more important role in cognitive development. And, perhaps, the high grades could be attributed to good teaching.

Recommendations.

This research study determined that the majority of WC_3 College General Biology students are at the concrete level of cognitive development. Most college biology courses are taught at the formal level of cognitive development. This discrepancy between the students' level of cognitive development and the teachers' level of instruction can lead to teacher and student frustration, drop-outs and a continuation of the self-fulfilling prophecy of failure.

Since most instructors will be hesitant or adamant about changing their method of instruction, other ways can be found to enhance the students' achievement.

Teaching models, audio-visual aids and self-paced learning modules can be made available for students' use in the Learning Resource Center.

Since WC_3 has numerous computer terminals in specially equipped rooms staffed with computer lab assistants, computer assisted instruction (CAI) for units such as the metric system, chemical formulas and equations, genetic problems and ecology simulations could be available for students. Computer practice tests to alleviate test anxiety could also be available.

Students can be encouraged to utilize more effectively and efficiently the Student Services. These services include tutoring, mini courses in developing study skills and test skills using biofeedback techniques.

Exposure to additional "hands on" exercises in the biology labs could enhance cognitive development and thus achievement in science education. For example, special emphasis could be placed on hierarchial classification through the use of dichtomous keys; reversibility and proportional reasoning could be demonstrated using the metric system and genetic problems; combinatorial reasoning could be aided using several variables and control systems in photosynthetic experiments, organic compound experiments and enzyme experiments.

Though WC_3 is a community college with an open-door policy, the lack of diagnostic tests permits students to enroll in classes for which they are not academically skilled. The test instruments from this research study can be utilized as a diagnostic measure. They can assess the students' academic strengths as well as their academic weaknesses. The counselors/instructors can then direct the student to the appropriate remedial classes if necessary.

The results of the research study indicate that high risk students who are at the concrete level of cognitive development would benefit from the development of a remedial course which would emphasize reading, math and study skills in a biological framework. This type of remedial course would help develop the students' academic skills. By stressing skills necessary for scholastic achievement, this course would benefit the high risk student not only in future biology courses but other academic areas as well. It is unfortunate that students enter the community college scholastically unprepared. Conceptually, the students' skill deficiencies can be traced to their elementary schooling. To prevent underprepared community college students, the elementary school must provide students with cognitive skills development. This can be best accomplished through properly utilizing their science classes to stress skills in math, reading and reasoning.

Future research studies could be conducted on other pre-requisite science classes, such as General Chemistry and General Physics. The data from students enrolled in these courses could be compared with the data from students in the General Biology course noting similarities and differences in cognitive skills and achievement.

Studies could also be conducted on advanced science classes to determine if exposure to additional science classes increases the students' cognitive skills and lower their failure rate.

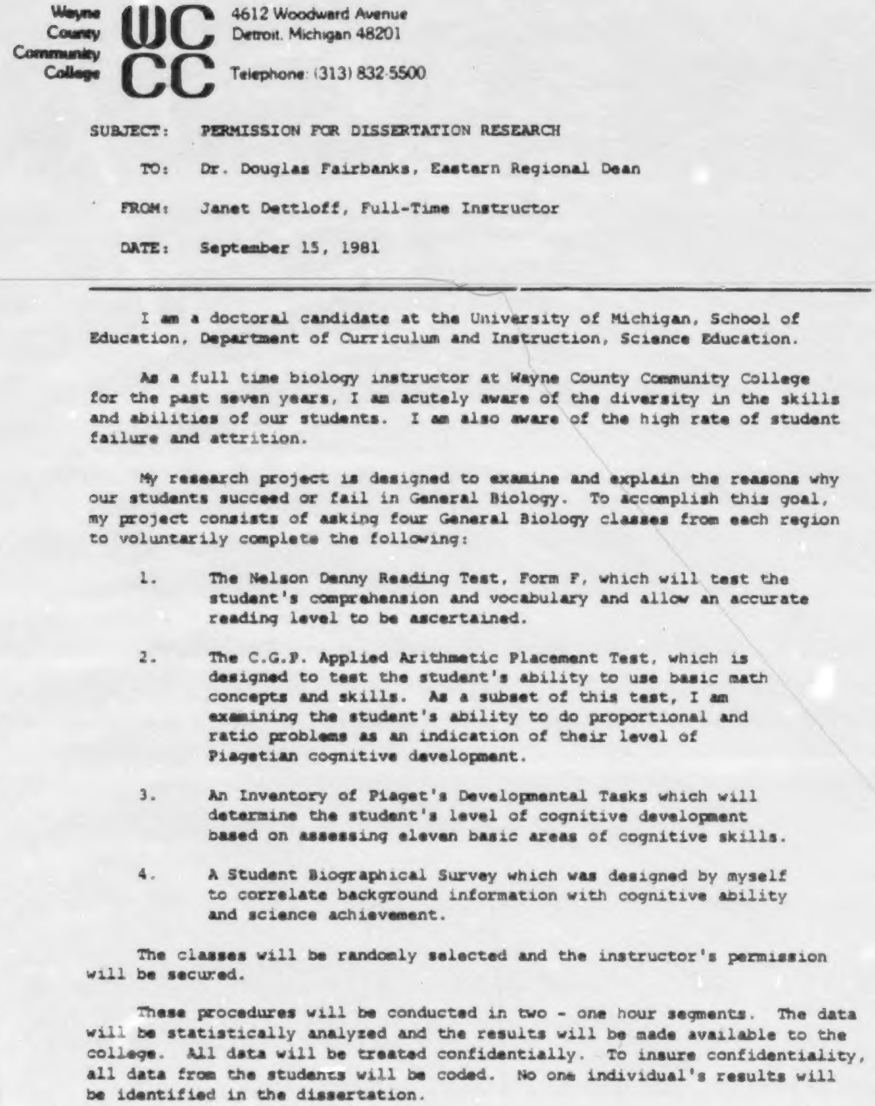
If these test measures were used as a diagnostic measure prior to enrollment, those students identified as high risk could then be offered the option of taking the remedial skills course before enrolling in the Biology course.

Proper utilization and interpretation of these test measures could help prevent the open door from becoming a revolving door.

APPENDICES

APPENDIX A

REQUEST FOR PERMISSION FOR RESEARCH STUDY



Wayne County Community College
WCCC
4612 Woodward Avenue
Detroit, Michigan 48201
Telephone: (313) 832-5500

SUBJECT: PERMISSION FOR DISSERTATION RESEARCH

TO: Dr. Douglas Fairbanks, Eastern Regional Dean

FROM: Janet Dettloff, Full-Time Instructor

DATE: September 15, 1981

I am a doctoral candidate at the University of Michigan, School of Education, Department of Curriculum and Instruction, Science Education.

As a full time biology instructor at Wayne County Community College for the past seven years, I am acutely aware of the diversity in the skills and abilities of our students. I am also aware of the high rate of student failure and attrition.

My research project is designed to examine and explain the reasons why our students succeed or fail in General Biology. To accomplish this goal, my project consists of asking four General Biology classes from each region to voluntarily complete the following:

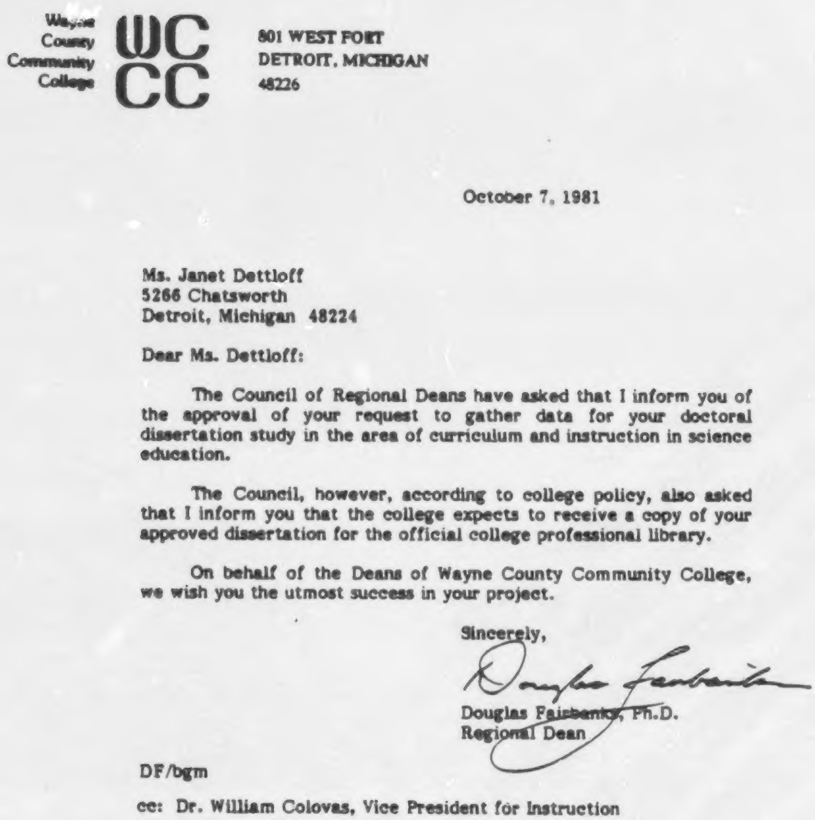
1. The Nelson Denny Reading Test, Form F, which will test the student's comprehension and vocabulary and allow an accurate reading level to be ascertained.
2. The C.G.P. Applied Arithmetic Placement Test, which is designed to test the student's ability to use basic math concepts and skills. As a subset of this test, I am examining the student's ability to do proportional and ratio problems as an indication of their level of Piagetian cognitive development.
3. An Inventory of Piaget's Developmental Tasks which will determine the student's level of cognitive development based on assessing eleven basic areas of cognitive skills.
4. A Student Biographical Survey which was designed by myself to correlate background information with cognitive ability and science achievement.

The classes will be randomly selected and the instructor's permission will be secured.

These procedures will be conducted in two - one hour segments. The data will be statistically analyzed and the results will be made available to the college. All data will be treated confidentially. To insure confidentiality, all data from the students will be coded. No one individual's results will be identified in the dissertation.

APPENDIX B

APPROVAL OF RESEARCH STUDY



Wayne
County
Community
College
WC
CC

801 WEST FORT
DETROIT, MICHIGAN
48226

October 7, 1981

Ms. Janet Dettloff
5266 Chatsworth
Detroit, Michigan 48224

Dear Ms. Dettloff:

The Council of Regional Deans have asked that I inform you of the approval of your request to gather data for your doctoral dissertation study in the area of curriculum and instruction in science education.

The Council, however, according to college policy, also asked that I inform you that the college expects to receive a copy of your approved dissertation for the official college professional library.

On behalf of the Deans of Wayne County Community College, we wish you the utmost success in your project.

Sincerely,

Douglas Fairbanks

Douglas Fairbanks, Ph.D.
Regional Dean

DF/bgm

cc: Dr. William Colovas, Vice President for Instruction

APPENDIX C

RANDOM SELECTION PROCEDURES

The method used to select the classes randomly was:

1. List all the General Biology classes by region.
2. Using the first two numbers on a dollar bill, flip a quarter to determine whether the first or second number was used to enter the random number table. A separate dollar bill was used for each region.
3. Consult the random number table until a different one digit number for each class was assigned at each region.
4. Place all the numbers in a jar. Shake well. Draw out one number. Select the class corresponding with that number. Return the number to the jar.
5. Follow the same procedure for all regions except the Western Region, which has only four classes.

APPENDIX D

THE COLLEGE BIOLOGY STUDENT SURVEY

Wayne County Community College

College Biology Student Survey

Social Security Number________________

PUT YOUR ANSWERS ON THIS QUESTIONNAIRE

DIRECTIONS

Please circle the number or numbers of the answer(s) and fill in the blanks for the appropriate questions. Ignore the numbers on the right-hand side of the page.

1. Indicate your sex: (11)
   1. Male
   2. Female
2. Indicate your age: (12)
   1. 17 - 22
   2. 23 - 30
   3. 31 - 40
   4. 41 - 50
   5. Over 50
3. Indicate your race: (13)
   1. White
   2. Black
   3. Arabian
   4. Hispanic
   5. Oriental
   6. Other (please specify)____________________
4. Are you: (14)
   1. Single
   2. Married
   3. Living together
   4. Separated, Divorced, Widowed

5. Did you attend high school at any time? (15)

    1. Yes

    2. No

6. Did you graduate from high school? (16)

    1. Yes

    2. No

IF YOUR ANSWER TO QUESTION 6 IS NO, THEN ANSWER QUESTIONS 7, 8, AND 9.

IF YOUR ANSWER TO QUESTION 6 IS YES, THEN GO TO QUESTION 10.

7. What was the last grade you attended in high school? (17)

    1. Freshman - grade 9

    2. Sophomore - grade 10

    3. Junior - grade 11

    4. Senior - grade 12

8. Did you take the GED (General Education Diploma)? (18)

    1. Yes

    2. No

9. Did you pass the GED? (19)

    1. Yes

    2. No

10. Indicate how long it was from the time you completed or left high school until you started college (any college, including WC_3): (20)

    1. Less than 1 year

    2. One to five years

    3. Six to ten years

    4. Eleven to fifteen years

    5. More than fifteen years.

11. Since you first attended college (any college), did you stop attending college and then return (excluding summer vacation)? (21)

    1. Yes

    2. No

IF YOUR ANSWER TO QUESTION 11 IS YES, THEN ANSWER QUESTIONS 12, 13, AND 14.

IF YOUR ANSWER TO QUESTION 11 IS NO, THEN GO TO QUESTION 15.

12. How many years were you out of college before returning to college? (22-23)

    ________________ years

13. How many years have you attended college either full- or part-time since you left high school? (Do NOT include the time you were not in college.) (24-25)

    ________________ years

14. List your occupation(s) (for example, factory worker, sales-clerk, clerical, etc.) during the time(s) you were not in college: (26-28)

Occupation	Dates
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

15. Indicate the number of credit hours you are taking this semester: (29)

    1. 4

    2. 5 - 8

    3. 9 - 11

    4. 12 - 17

    5. Over 17

16. Are you working now? (30)

    1. Yes

    2. No

IF YOUR ANSWER TO QUESTION 16 IS YES, THEN ANSWER QUESTIONS 17 AND 18.

IF YOUR ANSWER TO QUESTION 16 IS NO, THEN GO TO QUESTION 19.

17. Indicate the number of hours you work per week: (31)

    1. 1 - 10 hours
    2. 11 - 20 hours
    3. 21 - 30 hours
    4. 31 - 40 hours
    5. Over 40 hours

18. Indicate your current occupation (excluding student): (32)

    ____

19. Do you live: (33)

    1. At home with your parents
    2. With a mate (husband/wife/roommate(s))
    3. Alone

20. Do you have children? (34)

    1. Yes
    2. No

IF YOUR ANSWER TO QUESTION 20 IS YES, THEN ANSWER QUESTIONS 21 AND 22.

IF YOUR ANSWER TO QUESTION 20 IS NO, THEN GO TO QUESTION 23.

21. Indicate the number of children living with you: (35-36)

    ____

22. How many of these children are dependent on you for their support? (37-38)

    ____

23. What was your total family income in 1980 before taxes and deductions? (39)

    1. 0 - $4,999
    2. $5,000 to $9,999
    3. $10,000 to $14,999
    4. $15,000 to $19,999
    5. $20,000 and over

24. Indicate all the financial resource(s) that enable you to attend WC_3 and meet your living expenses: (40-45)

    1. Support from parents
    2. Earnings from job
    3. Support from spouse/mate
    4. Student loan
    5. Veteran's Bill
    6. BEOF (Basic Educational Opportunity Grant) or Pell Grant
    7. Scholarship
    8. Michigan Opportunity Grant
    9. Other state and federal government sources (ADC, Social Security, etc.)
    10. Other (please specify) ____________________

25. Indicate your father's occupation. If your father is retired or deceased, indicate his major occupation while employed: (46)

    ____

26. Is your mother employed now, or was she previously, employed? (47)

    1. Yes, full-time
    2. Yes, part-time
    3. No.

27. If yes, indicate your mother's occupation: (48)

    ____

28. Indicate how much schooling (formal education) your parents or the persons who raised you have. Check the blank that applies for the Male/Father and the Female/Mother: (49) (50)

Male/Father		Female/Mother
________	Grade school	________
________	Some high school	________
________	Finished high school	________
________	Technical school	________
________	Some college	________
________	Associate degree	________
________	Bachelor's degree	________
________	Graduate school	________
________	Don't know	________

29. Indicate the number of brothers and sisters you have. Include adopted/step/half brothers and sisters: (51-52) (53-54)

1. Brothers ____________
2. Sisters ____________
3. None ____________

IF YOUR ANSWER TO QUESTION 29 IS NONE, THEN GO TO QUESTION 34.

30. How many of your brothers and sisters finished high school? (55) (56)

1. Brothers ____________
2. Sisters ____________

31. How many of your brothers and sisters plan to attend college? (57) (58)

1. Brothers ____________
2. Sisters ____________

32. How many of your brothers and sisters are currently attending college? (59) (60)

1. Brothers ______________
2. Sisters ______________

33. How many of your brothers and sisters have finished college? (61) (62)

1. Brothers ______________
2. Sisters ______________

34. Indicate all the math classes taken and passed WHILE ATTENDING HIGH SCHOOL: (63-70) (71-77)

Math Classes	Taken	Passed (Yes or No)
Refresher Math	____	________
Basic/General Math	____	________
Business Math	____	________
Bookkeeping	____	________
Pre-algebra	____	________
First year Algebra	____	________
Second year Algebra	____	________
First year Geometry	____	________
Second year Geometry	____	________
Trigonometry	____	________
Pre-calculus	____	________
Calculus	____	________
Computer Math	____	________

Other (please specify) ____

35. Indicate all the science classes taken and passed WHILE ATTENDING HIGH SCHOOL:

(5- 9)
(10-14)

Science Classes	Taken	Passed (Yes or No)
Physical Science		
General Science		
Earth Science		
Biology		
Chemistry		
Physics		

36. Indicate all the math classes (basic arithmetic, algebra, etc.) taken and passed WHILE ATTENDING COLLEGE, ADULT EDUCATION CLASSES, TECHNICAL OR BUSINESS SCHOOL:

(15-19)
(18-2

Math Classes Taken	Passed (Yes or No)

37. Indicate all the science courses (hygiene, chemistry, physics, etc.) taken and passed WHILE ATTENDING COLLEGE, ADULT EDUCTION CLASSES, TECHNICAL OR BUSINESS SCHOOL:

(21-23)
(24-26)

Science Classes Taken	Passed (Yes or No)

38. Indicate your reason(s) for attending WC_3: (27-33)

1. Learning for its own sake
2. To meet people/make friends
3. To achieve a personal goal
4. To improve yourself
5. To get a promotion or raise
6. Low Cost
7. Closeness to home
8. Has the program I wanted
9. Other (please specify) ______________________

39. Indicate your course of study or program. (34)

1. Vocational/technical/business
2. Allied health programs
3. Liberal arts leading to an associate degree
4. General Transfer program
5. Don't know
6. Other (please specify) ______________________

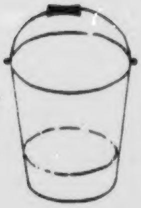
APPENDIX E

AN INVENTORY OF PIAGET'S DEVELOPMENTAL TASKS

developed by the
Center for Research
in Thinking and Language
Department of Psychology
Catholic University
Washington D.C. 20017

example

Which pail has the most water?



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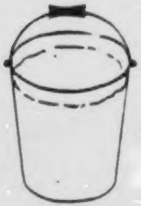

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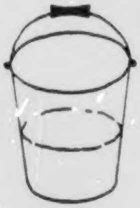

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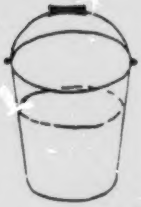


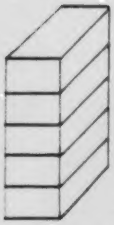
D

1

Here are some blocks.

The blocks are put into piles.

Which pile has the most blocks?



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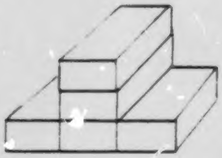

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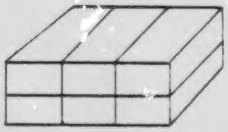

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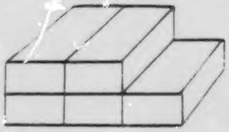
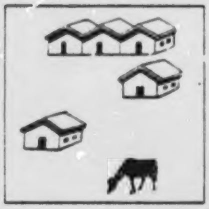


D

2

Here is a hungry horse.

Where does the horse get the most grass to eat?



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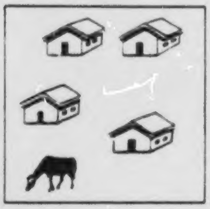

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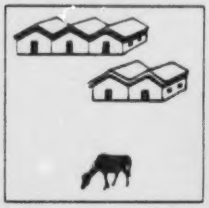

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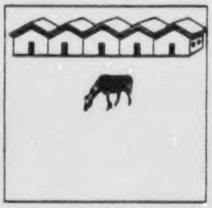
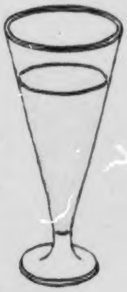


D

3

Which one has the most water?



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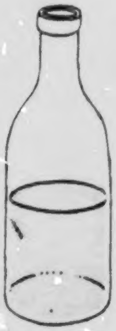

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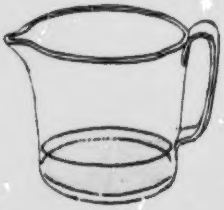

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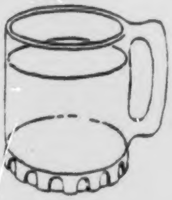
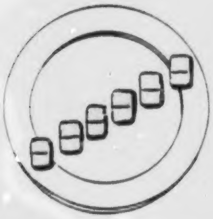


D

4

Here are some cookies.

Which plate has the most cookies?



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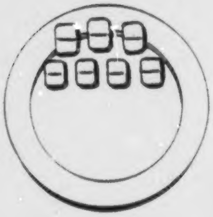

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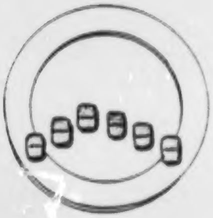

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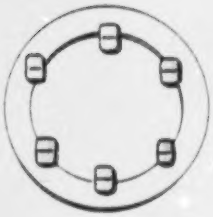

D

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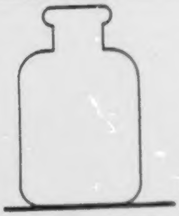
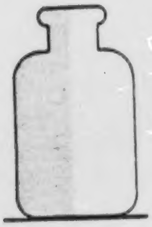
example



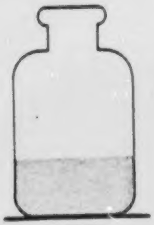
Here is a bottle on a table.

We put water in the bottle.

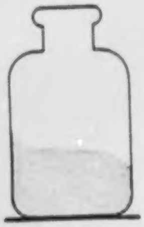
What does the water look like in the bottle?



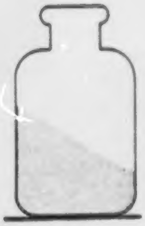
A



[✓ B]

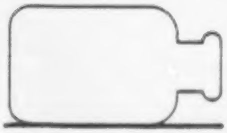


C



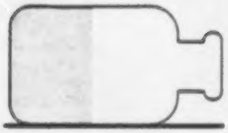
D

We turn the bottle this way.

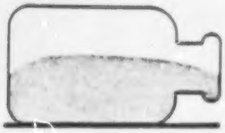


5

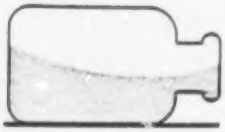
What does the water look like?



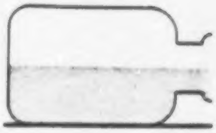
A



B

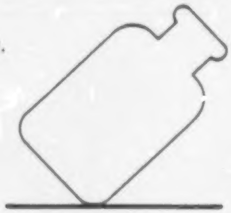


C



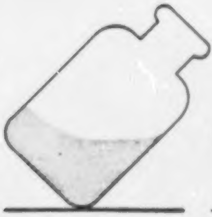
D

Now we turn the bottle this way.

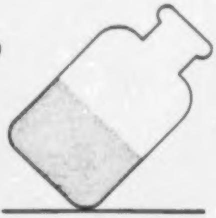


6

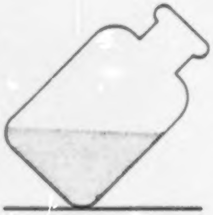
What does the water look like?



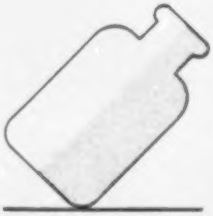
A



B



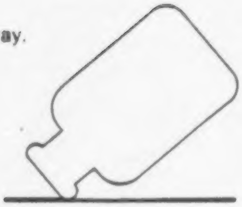
C



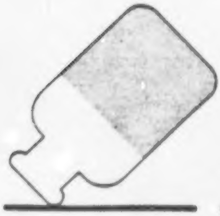
D

7

Now we turn the bottle this way.



What does the water look like?



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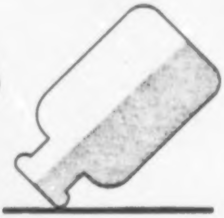

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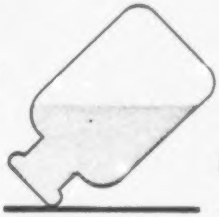

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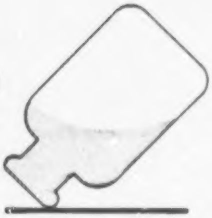
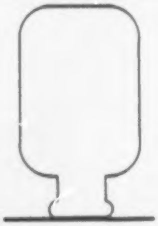


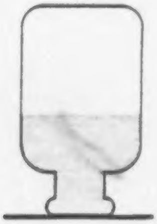
D

8

Now we turn the bottle this way.



What does the water look like?



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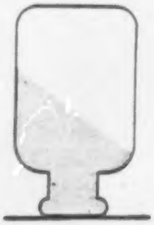
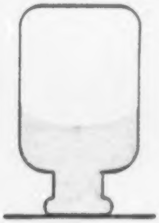
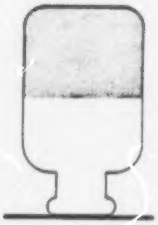


B

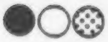
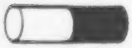


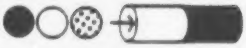
C



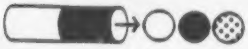
D

example

Here are 3 balls  and a tube. 

We roll the balls into the tube this way. 

How do they come out?



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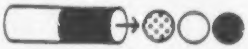
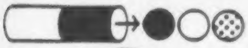
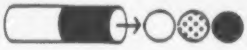


B

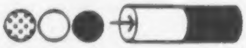


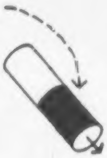
[✓ C]



D

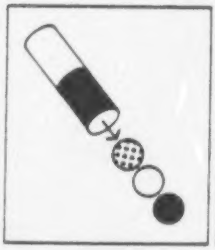
9

We put the balls into the tube this way. 

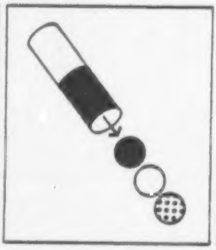


We turn the tube like this.

How do the balls come out?



A



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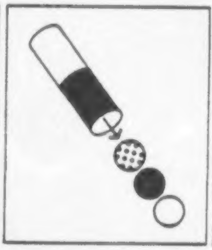
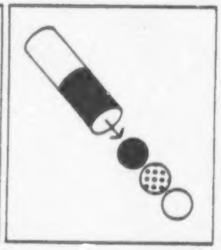


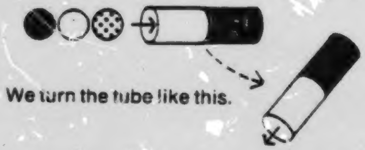
C



D

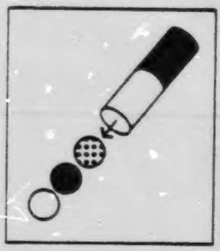
10

We put the balls into the tube this way

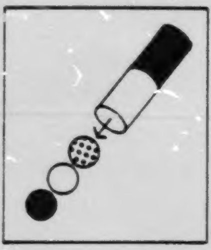


We turn the tube like this.

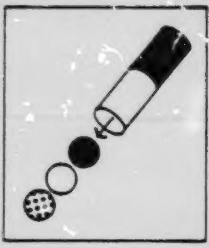
How do the balls come out?



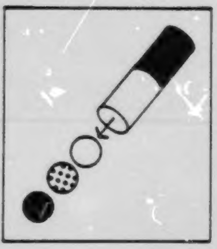
A



B



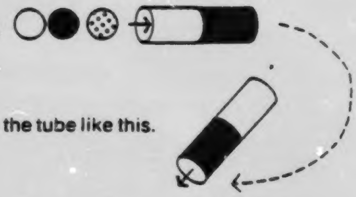
C



D

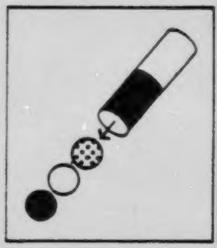
11

We put the balls into the tube this way.

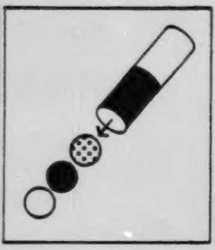


We turn the tube like this.

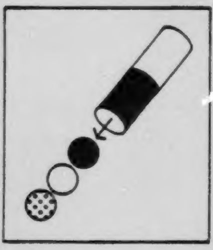
How do the balls come out?



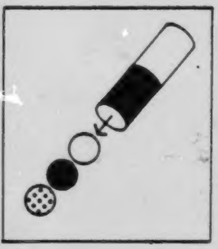
A



B



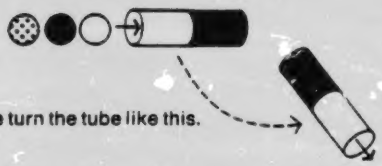
C



D

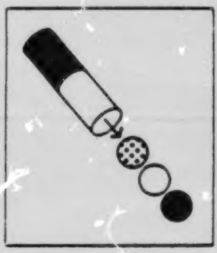
12

We put the balls into the tube this way.



We turn the tube like this.

How do the balls come out?



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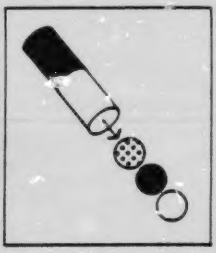
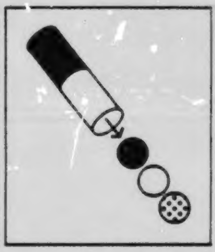
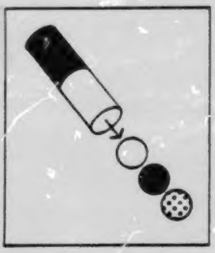


B



C



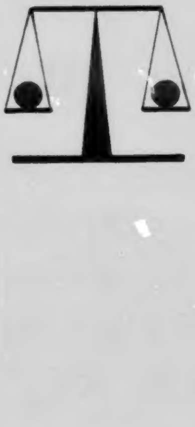
D

example

Here are two balls. ● ●

We put the balls on a balance scale.

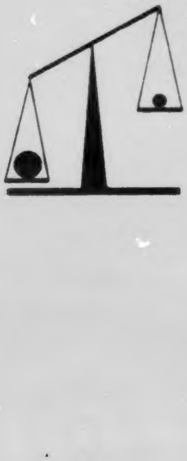
Look at the scale. The balls weigh the same.



Here are two other balls. ● •

Look at the scale

The big ball weighs more.



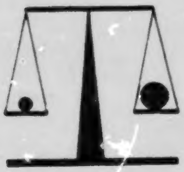
example

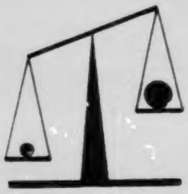
We have some clay.

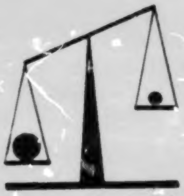
We make two balls, one big and one small. ● ●

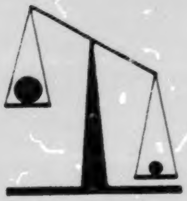
We put the balls on the scale.

What happens?


A


B


[✓ C]


D

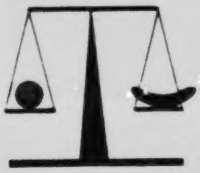
13

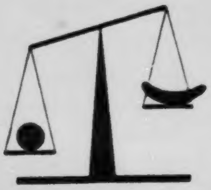
Here are two balls of clay. ● ●

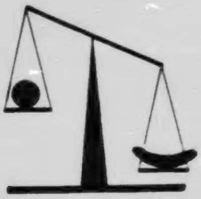
The balls weigh the same.

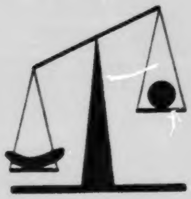
Now we make one ball look like a banana. ●

We put them on the scale. What happens?


A


B


C


D

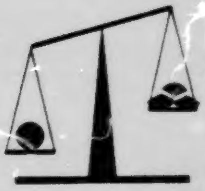
14

Here are two balls of clay. ● ●

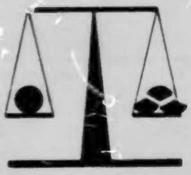
The balls weigh the same.

Now we cut one ball into 3 pieces. ●

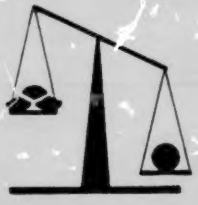
We put them on the scale. What happens?



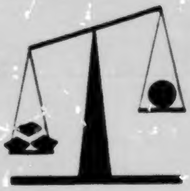
A



B



C



D

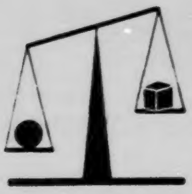
15

Here are two balls of clay. ● ●

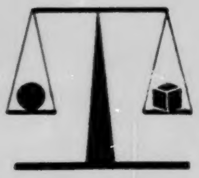
The balls weigh the same.

Now we make one ball look like a box. ●

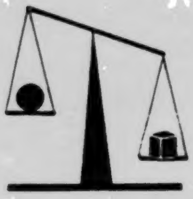
We put them on the scale. What happens?



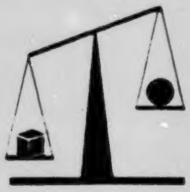
A



B



C



D

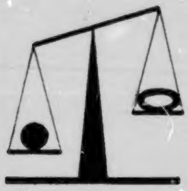
16

Here are two balls of clay. ● ●

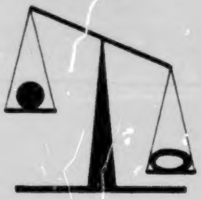
The balls weigh the same.

Now we make one of the balls into a ring. ● ○

We put them on the scale. What happens?



A



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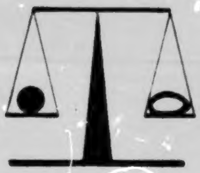

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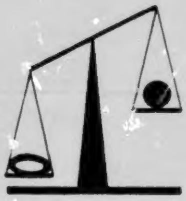
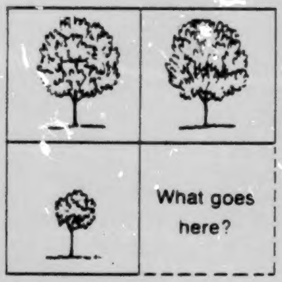


D

example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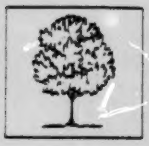

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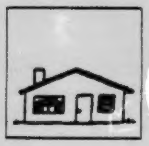

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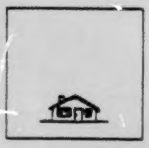

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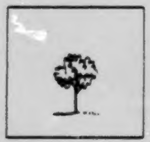
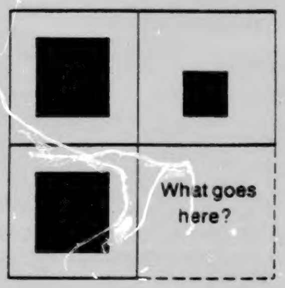


[✓ D]

17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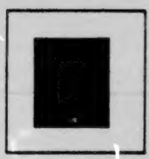
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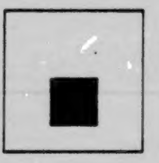
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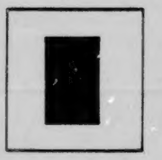
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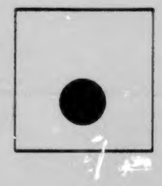
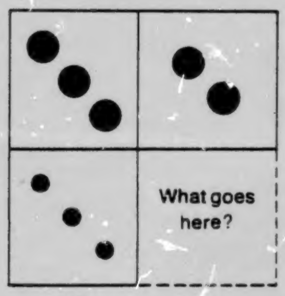

D

18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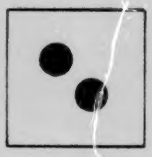
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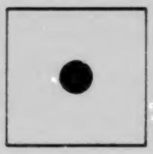
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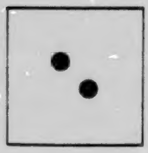
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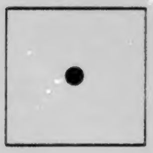
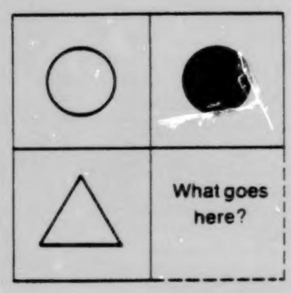

D

19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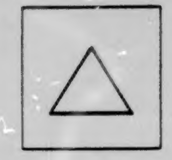
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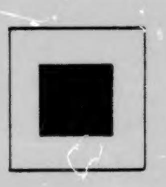
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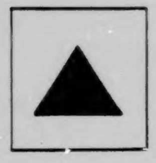
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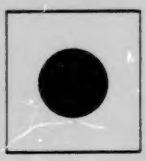
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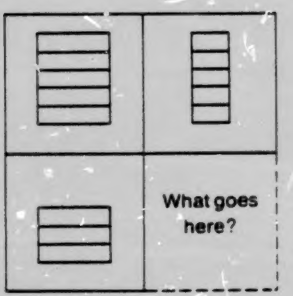
20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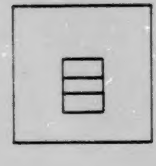
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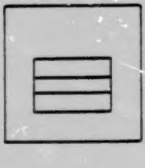
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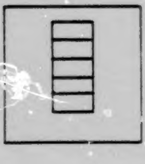
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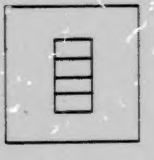
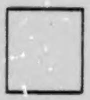
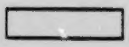

D

example

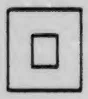
y =



x =



x+y = ?



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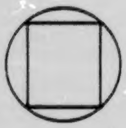

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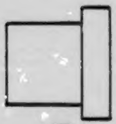
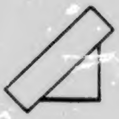


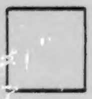
[✓ C]



D

21

x =



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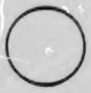

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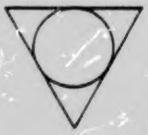

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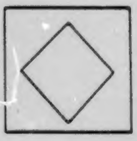

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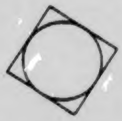

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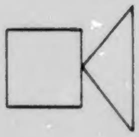

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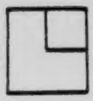
22

x+y=


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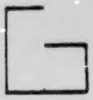

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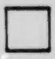
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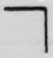
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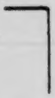
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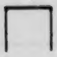
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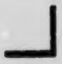

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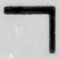

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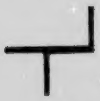
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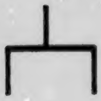
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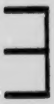
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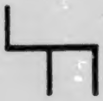
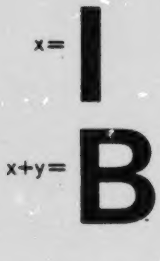

D

24



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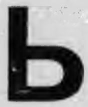
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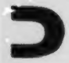
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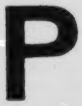
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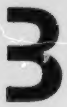
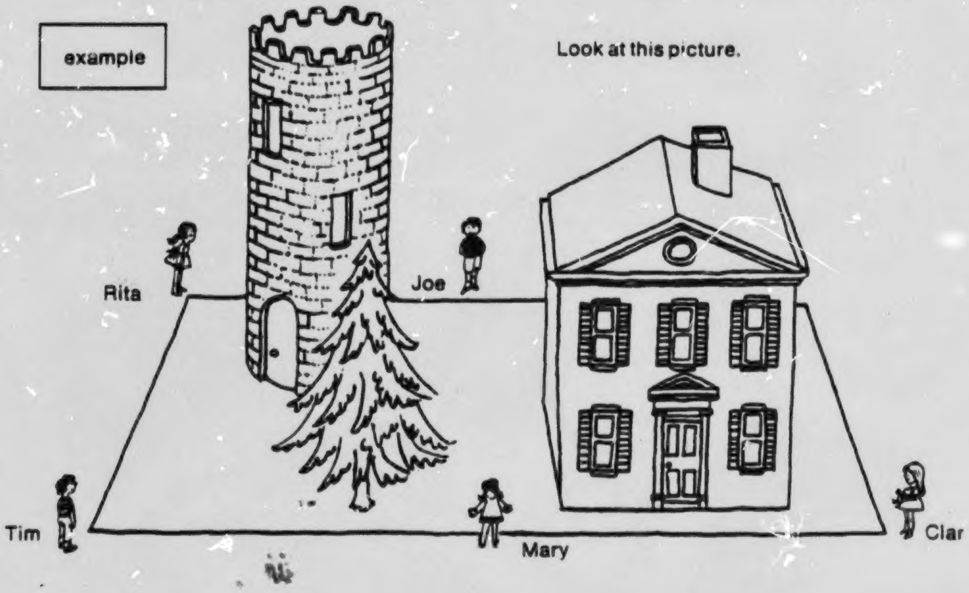

D

example

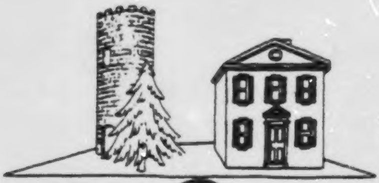
Look at this picture.


Rita
Joe
Tim
Mary
Clar

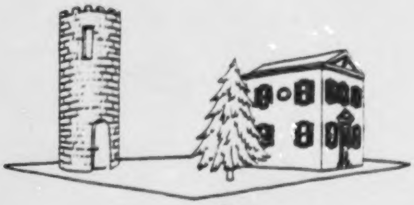
example

Look at the picture in the example on page 16.

What does Mary see?



[✓ A]



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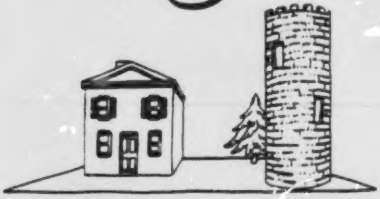

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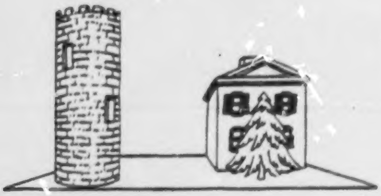
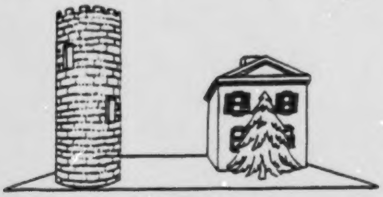


D

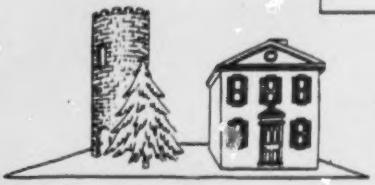
Look at the picture in the example on page 16.

What does Joe see?

25



A



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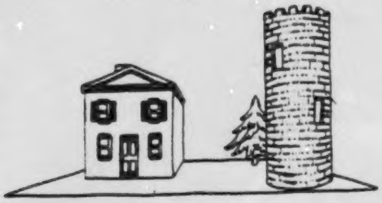

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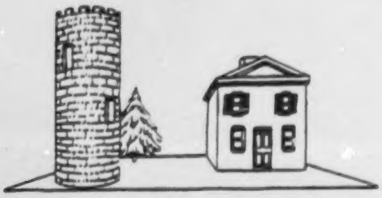
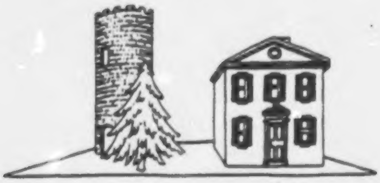


D

26

Look at the picture in the example on page 16.

What does Tim see?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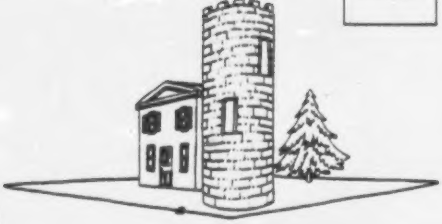
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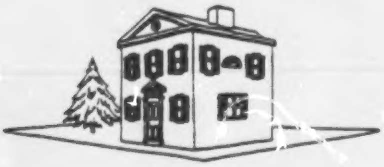
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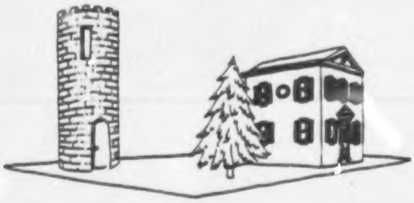
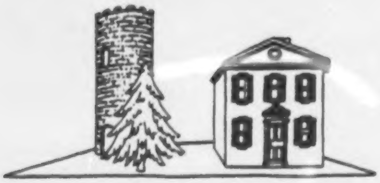

D

27

Look at the picture in the example on page 16.

What does Rita see?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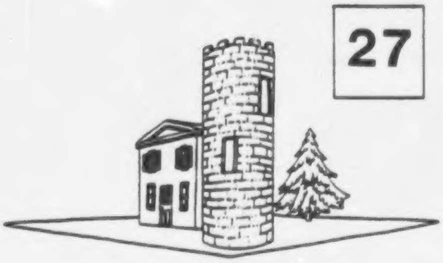
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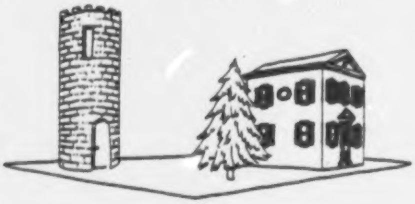
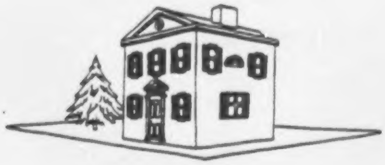
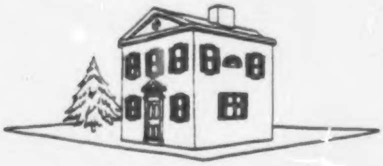

C


D

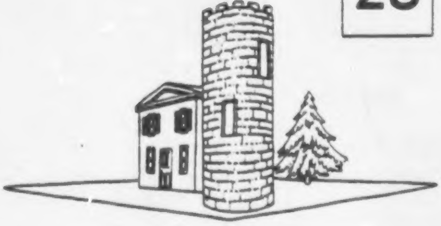
Look at the picture in the example on page 16.

What does Clara see?

28



A



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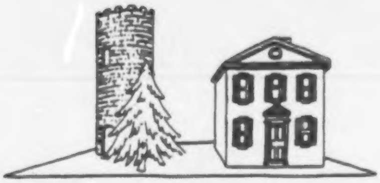

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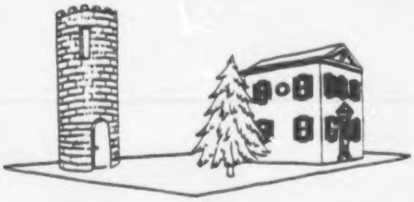
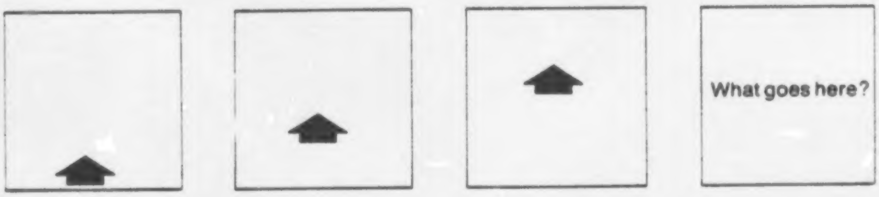
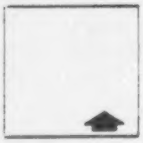


D

example


What goes here?



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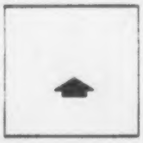

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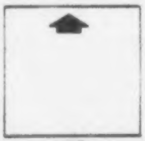
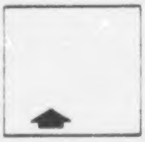
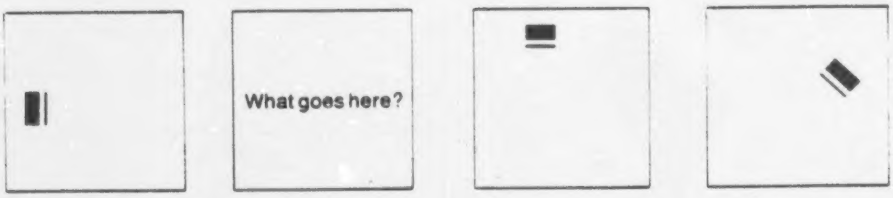


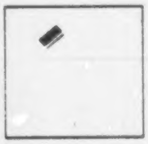
[✓ C]



D

29


What goes here?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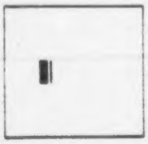
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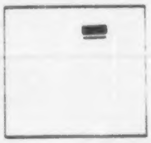
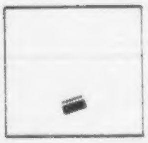
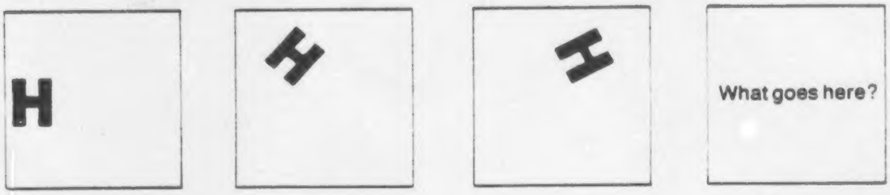
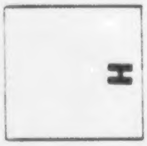
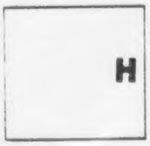

C

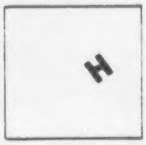

D

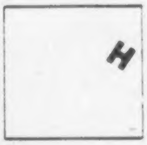
30


What goes here?

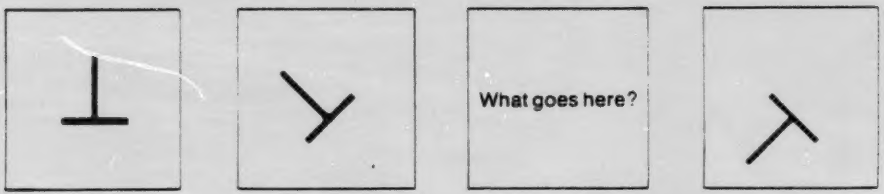

A

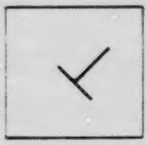

B

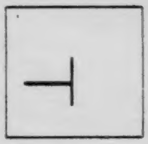

C


D

31


What goes here?


A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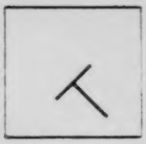
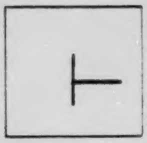
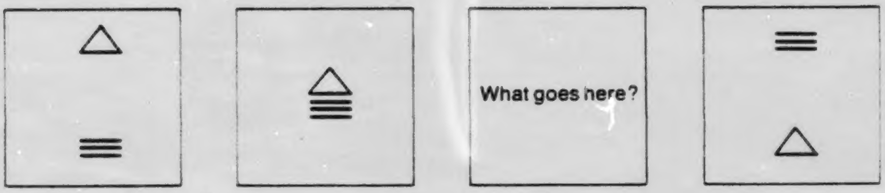
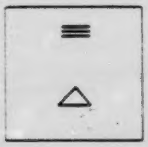
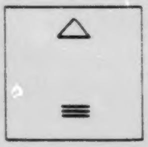

C

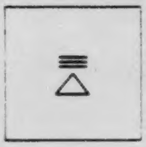

D

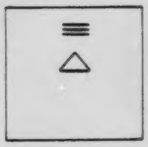
32


What goes here?


A


B

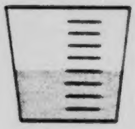

C


D

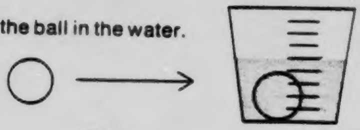
example

Here is a clay ball.

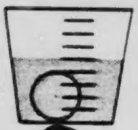
Here is a jar of water.



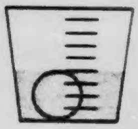
We put the ball in the water.



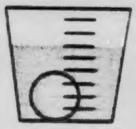
What happens ?



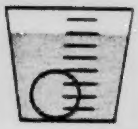
[✓ A]



B



C

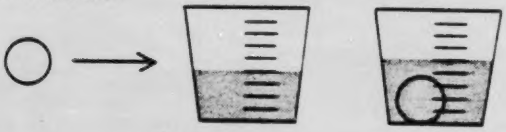


D

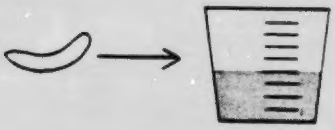
Here are two balls of clay.

We make one ball look like a banana.

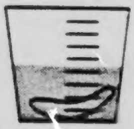
We put them in the water.



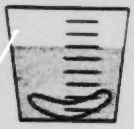
33



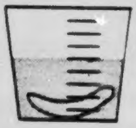
What happens?



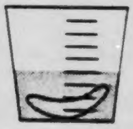
A



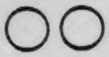
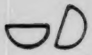
B



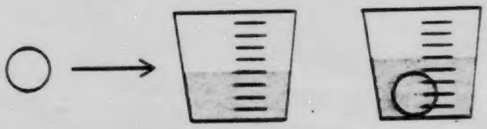
C

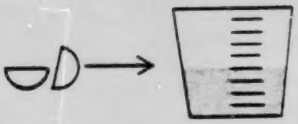


D

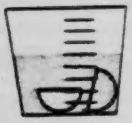
Here are two balls of clay.  Now we cut one ball into 2 pieces. 

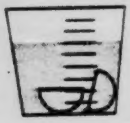
34

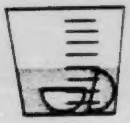


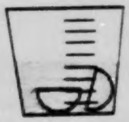


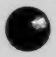
What happens?


A


B

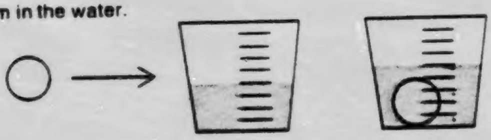

C

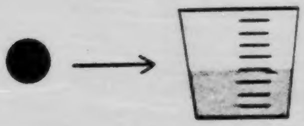

D

Here is a light ball. Here is a heavy ball. 

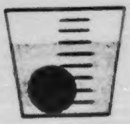
We put them in the water.

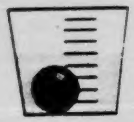
35

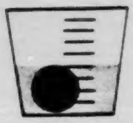


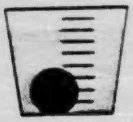


What happens with the heavy ball?


A

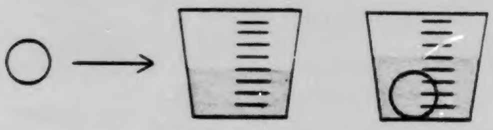

B

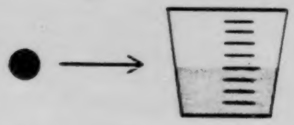

C


D

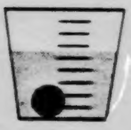
36

Here is a light ball. ○ Here is a small, heavy ball. ●

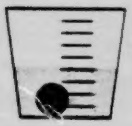




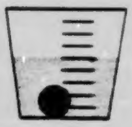
What happens with the small, heavy ball?



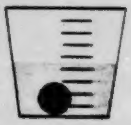
A



B



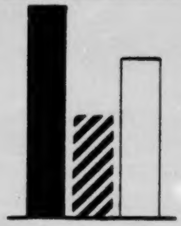
C



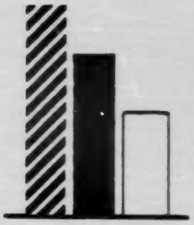
D

example

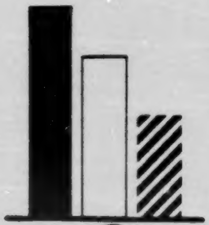
Here are 3 sticks.



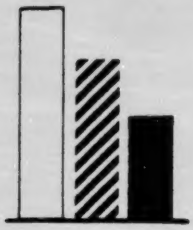
We line up the sticks from big to small. How do they look?



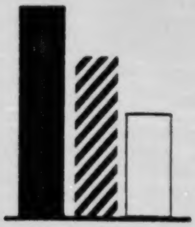
A



[✓ B]



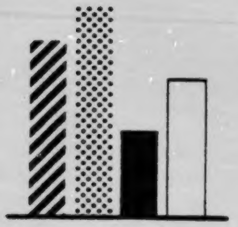
C



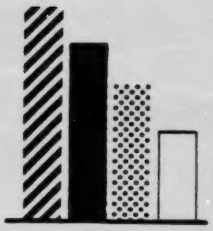
D

37

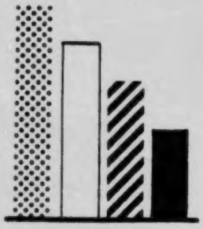
Here are 4 sticks.



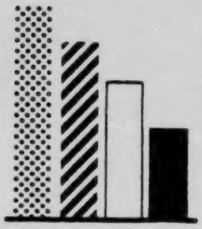
We line up the sticks from big to small. How do they look?



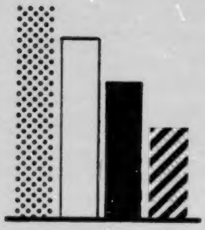
A



B



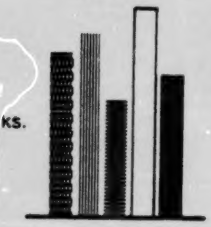
C



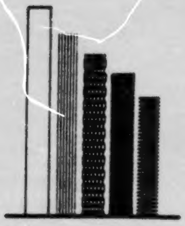
D

38

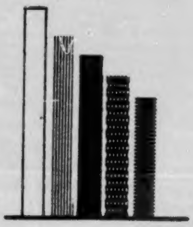
Here are 5 sticks.



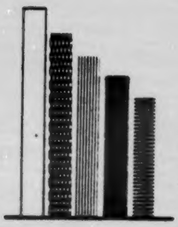
We line up the sticks from big to small. How do they look?



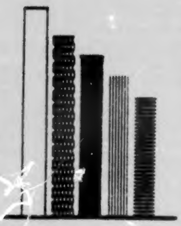
A



B



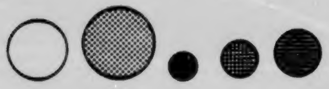
C



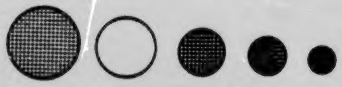
D

39

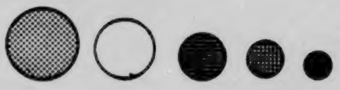
Here are five balls.



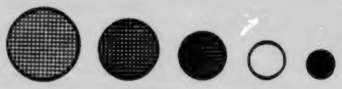
We line up the balls from big to small. How do they look?



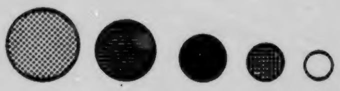
A



B



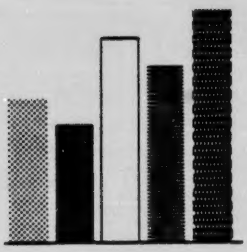
C



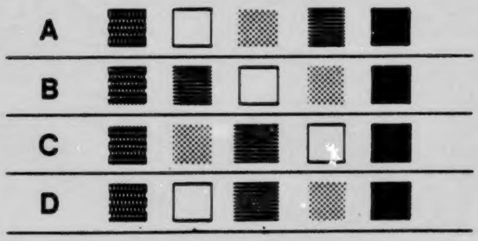
D

40

Here are five sticks.

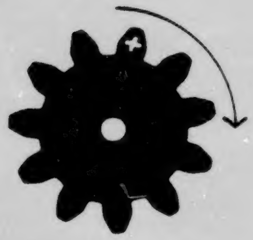


When the sticks are lined up from big to small which is the right order?

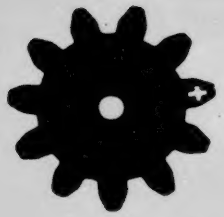


example

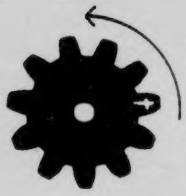
Here is a wheel.



The wheel turns down.

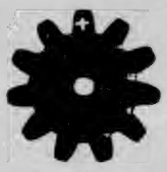


It looks like this.

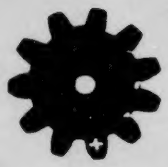


Now the wheel turns up this far.

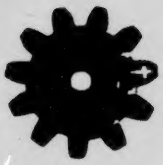
What does it look like?



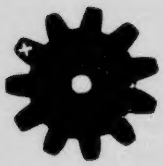
[✓ A]



B



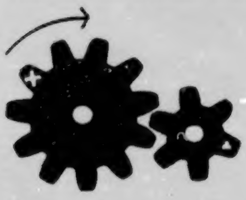
C

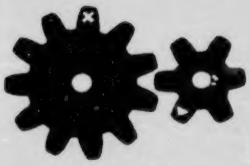


D

Here are two wheels. The big one turns up.

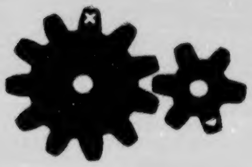
41



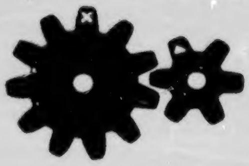


A

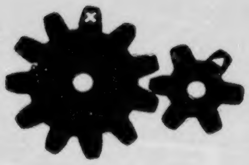
What do the wheels look like now?



B



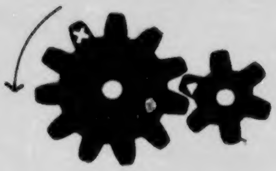
C

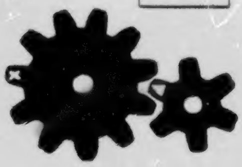


D

Here are two wheels. The big wheel turns down.

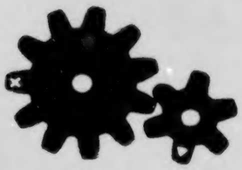
42



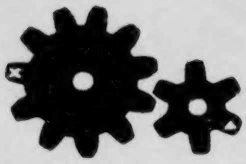


A

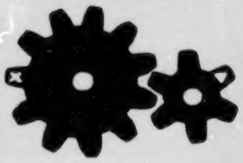
What do the wheels look like now?



B



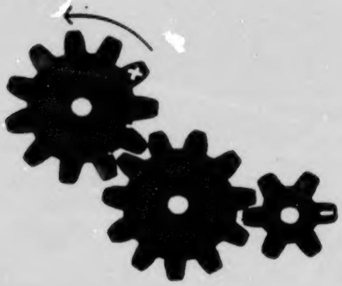
C



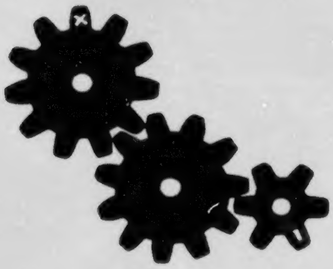
D

Here are three wheels. The left wheel turns up.

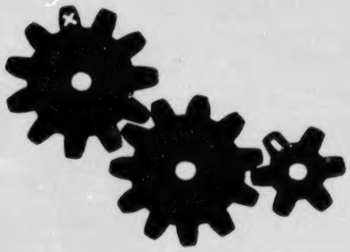
43



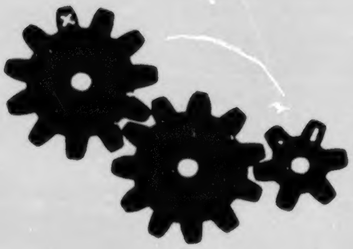
What do the wheels look like?



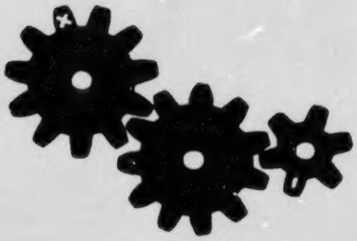
A



B



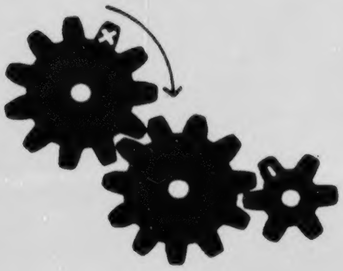
C



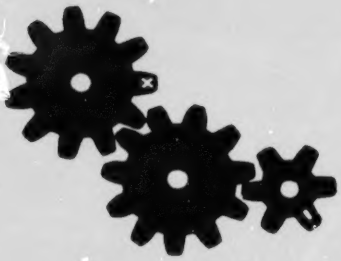
D

Here are three wheels. The left wheel turns down.

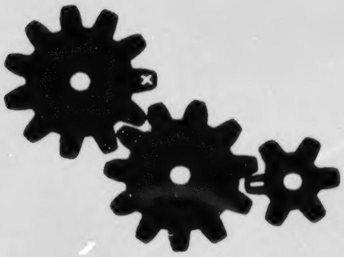
44



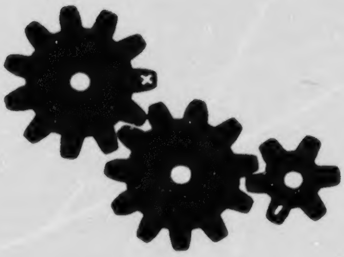
What do the wheels look like?



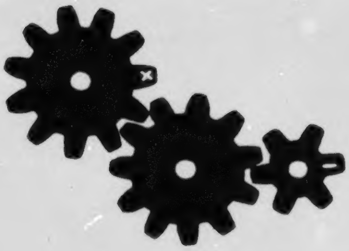
A



B



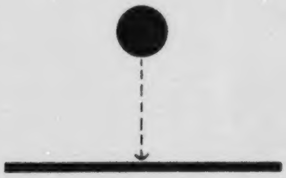
C



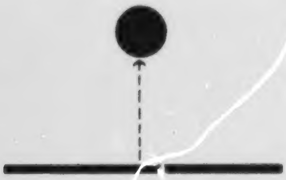
D

example

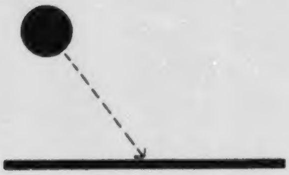
We throw the ball on the floor.



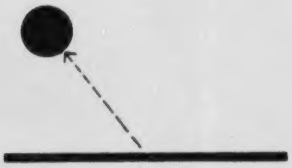
The ball bounces back.



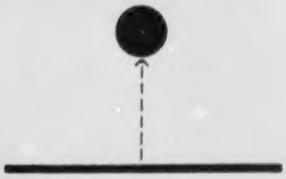
We throw the ball this way.



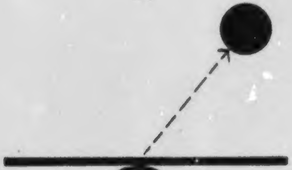
How does the ball bounce?



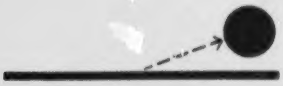
A



B



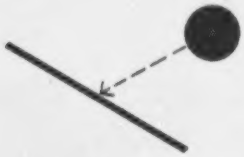
[✓ C]



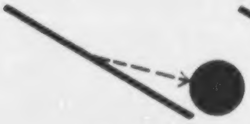
D

We throw the ball at a wall.

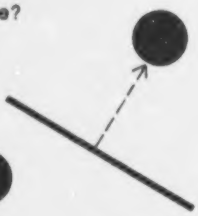
45



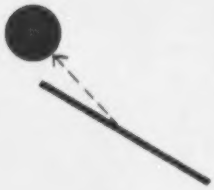
How does the ball bounce?



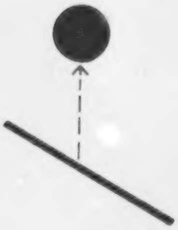
A



B



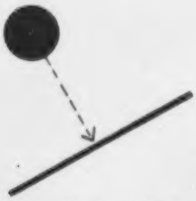
C



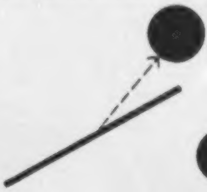
D

We throw the ball at a wall.

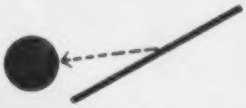
46



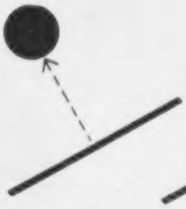
How does the ball bounce?



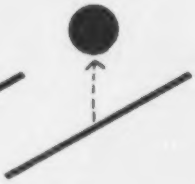
A



B



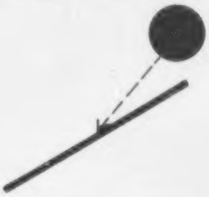
C



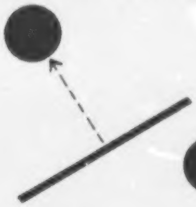
D

47

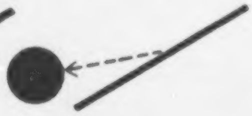
We throw the ball at a wall.



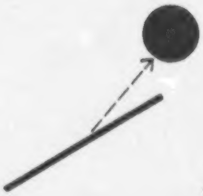
How does the ball bounce?



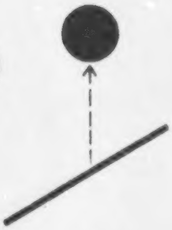
A



B



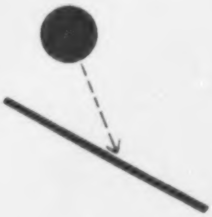
C



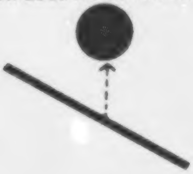
D

48

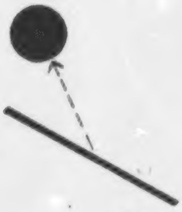
We throw the ball at a wall.



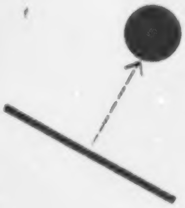
How does the ball bounce?



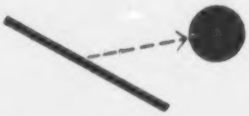
A



B

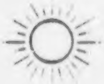


C

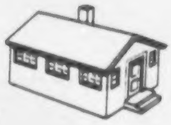


D

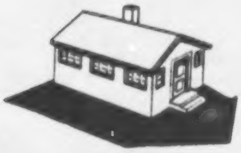
example



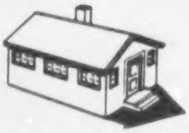
The sun is shining behind the house.



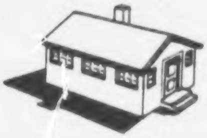
How does the shadow look?



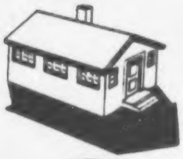
A



B

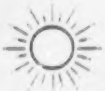


C

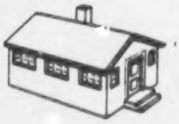


[✓ D]

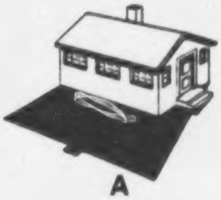
49



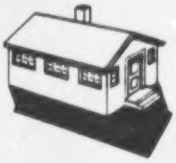
Now the sun moves here.



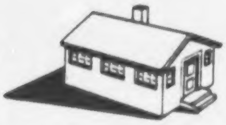
What does the shadow look like now?



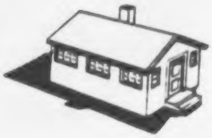
A



B

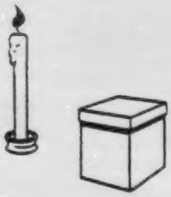


C



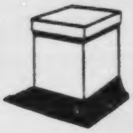
D

50

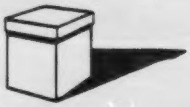


Here is a candle and a box.

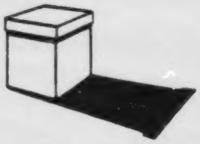
How does the shadow look?



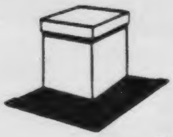
A



B



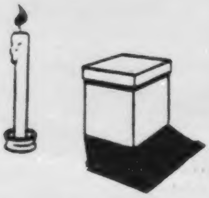
C



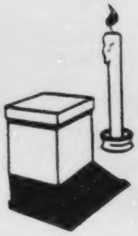
D

51

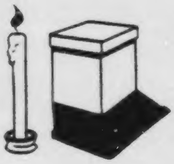
Which picture is right?



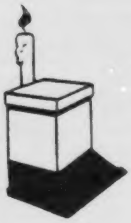
A



B



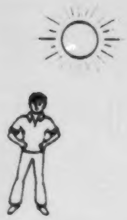
C



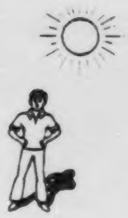
D

The sun shines on a man this way.

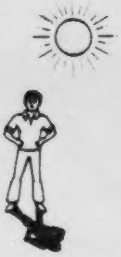
52



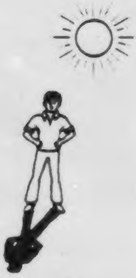
How does the shadow look?



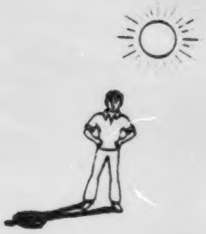
A



B



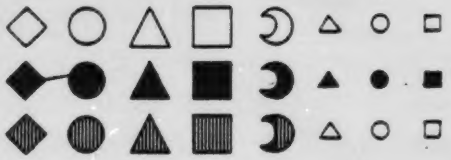
C



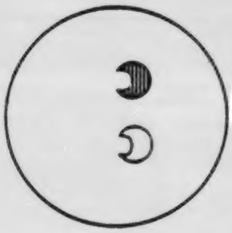
D

example

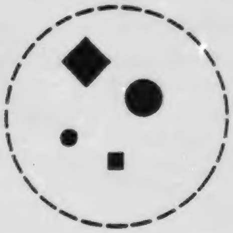
We have many different blocks like these.



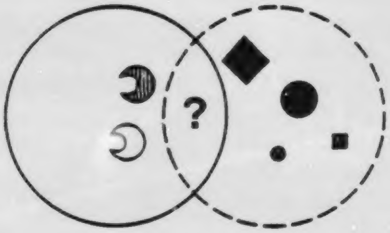
These blocks go in this circle.



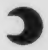
These blocks go in this circle.



We put the circles together like this.



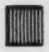
Which block belongs in the middle?



[✓ A]

B

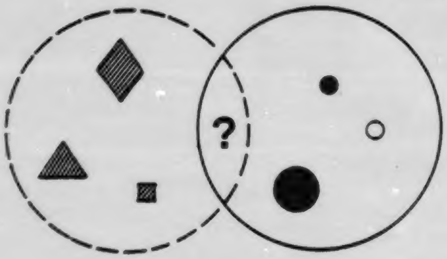
C



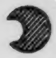
D

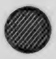
53

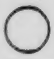
Here are two circles.



Which block belongs in the middle?


A

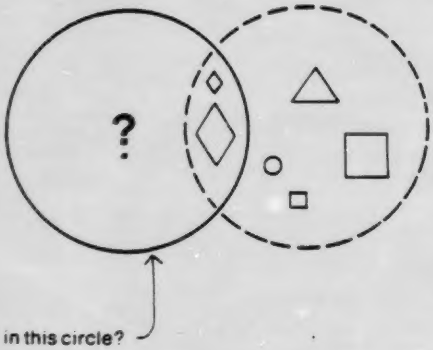

B


C

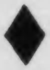
D

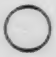
54

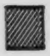
Here are two circles.



Which block belongs in this circle?


A

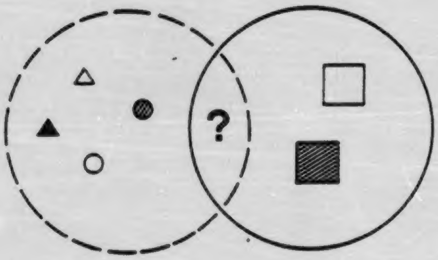

B


C

D

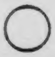
55

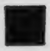
Here are two circles.



Which blocks belong in the middle?

A

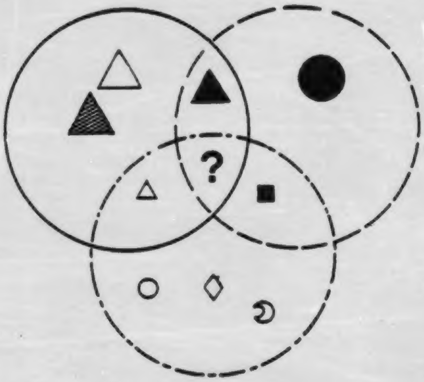

B


C

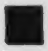
D

56

Here are three circles.



Which block belongs in the middle?


A

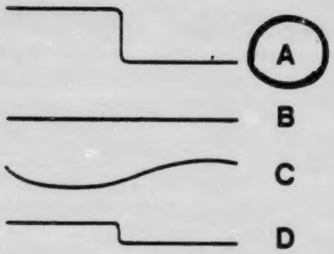
B

C

D

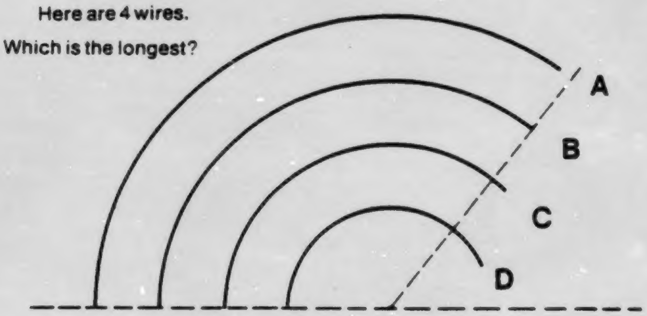
example

Here are 4 wires.
Which is the longest?



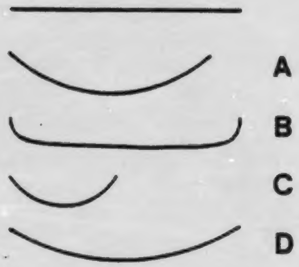
57

Here are 4 wires.
Which is the longest?



58

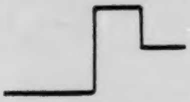
Here is a piece of wire.
We bend the wire.
What does it look like?

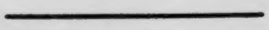


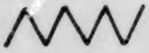
59

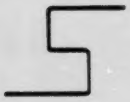
Here are 4 wires.

Which is the shortest?

A


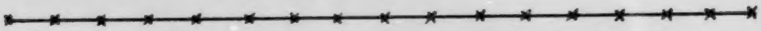
B


C


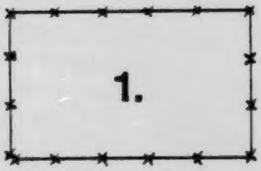
D


60

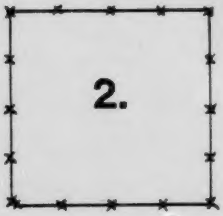
Here is a long piece of barbed wire.



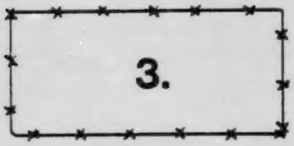
We bend it to make figure 1.



Then bend the same wire to make figure 2.



Then bend the same wire to make figure 3.



Which figure is the largest or are they all the same?

No. 1 largest
A

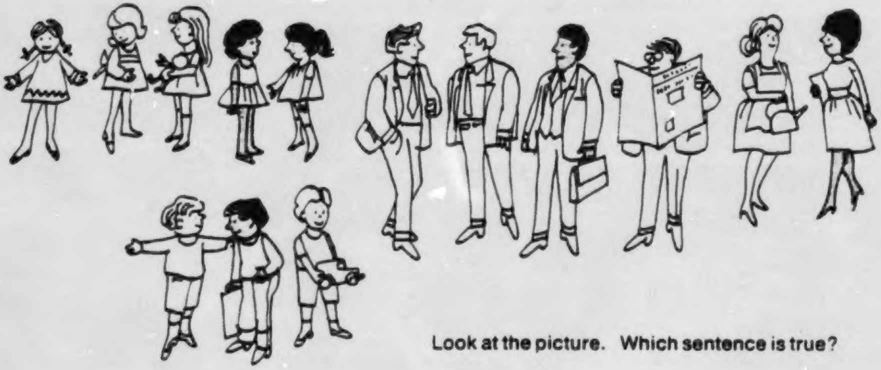
No. 2 largest
B

No. 3 largest
C

all the same
D

example

Here are many people.
There are 5 girls, 3 boys, 4 fathers and 2 mothers.



Look at the picture. Which sentence is true?

A There are more boys than girls.

B There are more adults than children.

[✓ **C**] There are more children than adults.

D There are more mothers than fathers.

61

Look at the picture. Which sentence is true?

A There are more fathers than adults.

B There are more mothers than fathers.

C There are more fathers than girls.

D There are more adults than fathers.

62

Look at the picture. Which sentence is true?

A There are more mothers than fathers.
B There are as many fathers as adult men.
C There are more fathers than adult men.
D There are more adult men than fathers.

63

Look at the picture. Which sentence is true?

A There are more boys than girls.
B There are more girls than children.
C There are as many girls as children.
D There are more children than girls.

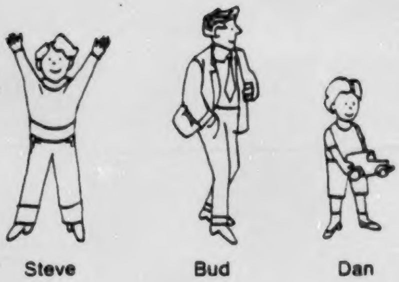
64

Look at the picture. Which sentence is true?

A There are more children than people.
B There are more people than children.
C There are as many children as people.
D There are more fathers than children.

example

Look at these three boys.



Which sentence is true?

- **A** Dan is bigger than Bud.
- [✓ **B**] Bud is bigger than Dan.
- **C** Steve is bigger than Bud.
- **D** Dan is bigger than Steve.

65

Now picture in your mind that:

Louis is bigger than Frank.
Frank is bigger than Joe.

Which sentence is true?

- **A** Joe is bigger than Frank.
- **B** Louis is bigger than Joe
- **C** Frank is bigger than Louis.
- **D** Joe is bigger than Louis.

66

Now picture in your mind that:

Henry is bigger than Victor.
John is not as big as Victor.

Which sentence is true?

- **A** John is bigger than Henry.
- **B** John is bigger than Victor.
- **C** Victor is bigger than Henry.
- **D** Henry is bigger than John.

67

Now picture in your mind that:

Don is not as big as Tom.
Bob is not as big as Don.

Which sentence is true?

- **A** Bob is bigger than Tom.
- **B** Bob is bigger than Don.
- **C** Tom is bigger than Bob.
- **D** Don is bigger than Tom.

68

Now picture in your mind that:

Jim is bigger than Al.
Al is bigger than Ron.
Dick is bigger than Jim.

Which sentence is true?

- **A** Ron is bigger than Jim.
- **B** Dick is bigger than Al.
- **C** Ron is bigger than Dick
- **D** Al is bigger than Dick.

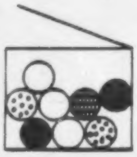
example

Here are some balls:

Some like this. ⊜ Some like this. ● Some like this. ◍ Some like this. ○

Now you put 8 balls into a box.

You shake the box.



You close your eyes and take out one ball.

Which ball do you guess you will take out?

○ ● ◍ ⊜

[✓ A] B C D

69

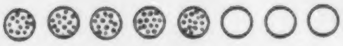
We put these balls into a box. ○ ◍ ◍ ◍

Which balls do you guess you will take out 1st and 2nd ?

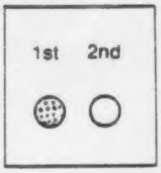
	A	B	C	D
1st	○	◍	○	◍
2nd	◍	◍	○	○

70

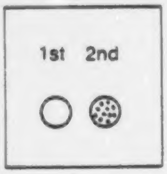
We put these balls into a box.



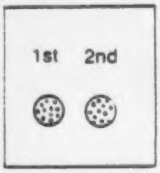
Which balls do you guess you will take out 1st and 2nd ?



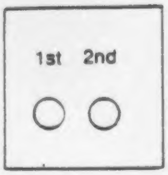
A



B



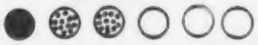
C



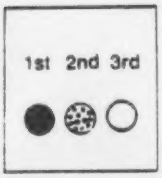
D

71

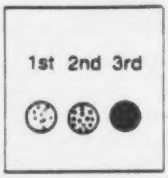
We put these balls into a box.



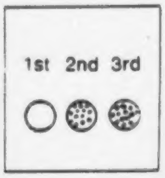
Which balls do you guess you will take out 1st, 2nd, and 3rd?



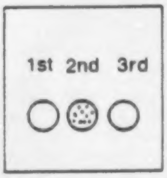
A



B



C



D

72

We put these balls into a box. ● ● ● ◍ ○ ○

Which balls do you guess you will take out 1st 2nd and 3rd?

	1st	2nd	3rd
A	●	○	●
B	●	◍	○
C	●	○	○
D	●	○	◍

APPENDIX F

STUDENT CONSENT FORM

I understand the purpose of this research project conducted by Janet M. Dettloff for her doctoral dissertation at The University of Michigan.

If I agree to participate in this project, I will complete the following forms:

1. General Biology Student Survey
2. Nelson-Denny Reading Test, Form F
3. The C.G.P. Applied Arithmetic Placement Test
4. An Inventory of Piaget s Developmental Tasks

I realize my participation in this project is completely voluntary, in whole or in part. This means that if I participate, I may choose to stop at any time on any instrument or on any question(s).

I understand that my final course grade will be used by the researcher in the data analysis.

I know the results will be confidential and coded and that the individual results will be unidentifiable when published in the dissertation.

Therefore, I agree to participate in this project.

____
Student's Signature

Janet Dettloff
Biology Instructor
Wayne County Community College

APPENDIX G

REPORT OF INDIVIDUAL SCORES

Dear WC_3 General Biology Student,

Thank you for participating in my research project. Your help and cooperation is greatly appreciated.

Although only group results will be used in the dissertation, I am pleased to provide your individual results as you requested.

Nelson-Denny Reading Test Form F:

Vocabulary Score ________

Comprehension Score ________

Reading Grade Level ________

Applied Arithmetic Placement Test:

Number Correct ________

These scores reflect your reading and math skills on the day the tests were administered. Should you feel either or both of these areas may be a problem, there are services available at the Institute for Human Resources to help you improve these skills.

Inventory of Piaget's Developmental Tasks:

Skill (the skill is underlined)	Have Skill	Do Not Have Skill
1. Ability to determine quantity		
2. Ability to determine proper levels of water		
3. Ability to determine sequence of balls in a tube		
4. Ability to determine weight/mass of clay balls		

Skill (the skill is underlined)	Have Skill	Do Not Have Skill
5. Ability to determine matrix by selecting the proper figure to match the other figures		
6. Ability to determine symbols x + y = ?		
7. Ability to determine perspective by observing the house from different viewpoints		
8. Ability to determine movement by selecting the appropriate figure to fit the movement of the other figures		
9. Ability to conserve volume by observing the level of water when various clay balls were dropped into the water		
10. Ability to arrange objects in a series		
11. Ability to perform rotation by determining how gears rotate		
12. Ability to determine angles using balls bounced off a flat surface		
13. Ability to determine shadows produced by various directions of sun and candles		
14. Ability to classify objects by selecting the correct figure to fit in the circles		
15. Ability to determine length/distance using wires bent into various shapes		
16. Ability to include using adults, children, boys, and girls		

Skill (the skill in underlined)	Have Skill	Do Not Have Skill
17. Ability to infer by determining who was larger		
17. Ability to do probability problems by determining the order of balls removed from a box		

It is not expected that everyone will answer all the questions correctly. You probably did best in those areas where you have past experiences. Therefore, the more kinds of experiences you have, the more likely you will have mastered various skills.

Many of these skills are taught in science and math classes. You may decide to take additional science and math classes to improve your skills.

Sincerely,

Janet Dettloff

APPENDIX H

TABLE OF DEMOGRAPHIC DATA

Variable	Category	N	%
Graduate High School	Yes	351	84
	No	69	16
Time from Leaving High School to Starting College	<1 year	176	42
	1 - 5 years	75	18
	6 - 10 years	60	14
	11 - 15 years	48	11
	>15 years	57	14
		416	99
Total Years Attended College	0 years	275	65
	1 year	39	9
	2 years	52	12
	3 - 5 years	61	14
		420	100
Number of Credit Hours	4	8	2
	5 - 8	88	21
	9 - 11	86	21
	12 - 17	231	55
	>17	7	2
		420	100

Variable	Category	N	%
Employed	Yes	218	52
	No	201	48
		419	100
Hours Worked Per Week	0	202	48
	1 - 10	9	2
	11 - 20	40	10
	21 - 30	46	11
	31 - 40	90	21
	>40	33	8
		420	100
Occupation	Professional	11	3
	Manager	8	2
	Sales	7	2
	Clerical	44	11
	Service	113	27
	Laborer	30	7
	Homemaker	199	47
		412	99

Variable	Category	N	%
Reasons for Attending WC_3	Program	126(420)	30(100)
	Learning for Own Sake	72	17
	Meet People (Friends)	37	9
	Achieve Personal Goal	294	70
	Improve Self	208	50
	Promotion/Raise	35	8
	Low Cost	101	24
	Closeness to Home	129	31
Courses of Study or Program	Vocational/Technical or Business	42	10
	Allied Health	230	55
	Liberal Arts	67	16
	General Transfer	54	13
	Don't Know	27	6
		420	100
Science Classes Passed in High School	Physical Science	118(420)	28(100)
	General Science	225	54
	Earth Science	84	20
	Biology	301	72
	Chemistry	131	32
	Physics	54	13

Variable	Category	N	%
Math Classes Passed in High School	Refresher Math	157(420)	37(100)
	Basic Math	272	65
	Business Math	112	27
	Bookkeeping	104	25
	Pre-Algebra	166	40
	First Year Algebra	235	56
	Second Year Algebra	128	31
	First Year Geometry	140	33
	Second Year Geometry	56	13
	Trigonometry	49	12
	Pre-Calculus	18	4
	Calculus	8	2
	Computer Math	16	4
Science Courses Passed in College	Hygiene	13(420)	3(100)
	First Aid	8	2
	Chemistry	34	8
	Physical Science	19	5
Math Courses Passed in College	Basic Arithmetic	75(420)	18(100)
	Elementary Algebra	40	10
	Intermediate Algebra	18	4
	College Algebra	20	5
	Plane Geometry	6	1

Variable	Category	N	%
Financial Resources	Parents	74	18
	Job	151	36
	Mate	45	11
	Student Loan	5	1
	GI Bill	7	2
	BEOG/Pell Grant	93	22
	Scholarship	10	2
	Other Government Sources	25	6
		410	98
Children	Yes	220	52
	No	196	47
		416	99
Total Family Income	0 - 4,999	63	15
	5 - 9,999	70	17
	10 - 14,999	102	24
	15 - 19,999	50	12
	>20,000	135	32
		420	100

APPENDIX I

SUMMARY OF THE 72 ITEM IPDT

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
1	370	88	49	12	--	--
2	111	26	309	74	--	--
3	319	76	101	24	--	--
4	398	95	21	5	--	--
5	378	90	41	10	--	--
6	374	89	45	11	--	--
7	347	83	72	17	--	--
8	390	93	29	7	--	--
9	352	84	67	16	--	--
10	353	84	66	16	--	--
11	321	76	98	24	--	--
12	343	82	76	18	--	--
13	371	88	48	11	--	--
14	381	91	38	9	--	--
15	383	91	36	9	--	--
16	361	86	58	14	--	--
17	381	91	38	9	--	--
18	368	88	51	12	--	--
19	366	87	53	13	--	--
20	345	87	54	13	--	--
21	402	96	17	4	--	--

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
22	225	54	194	46	--	--
23	333	79	85	20	2	1
24	383	91	34	8	3	1
25	229	54	188	45	3	1
26	248	59	170	41	2	1
27	262	62	155	37	3	1
28	338	81	79	19	3	1
29	297	71	120	29	3	1
30	166	40	252	60	2	1
31	260	62	156	37	4	1
32	365	87	53	13	--	--
33	300	71	119	28	--	--
34	329	78	88	21	3	1
35	182	43	237	56	--	--
36	128	31	289	69	3	1
37	386	92	33	9	--	--
38	385	92	33	8	2	1
39	381	91	37	9	2	1
40	372	89	44	11	4	1
41	153	36	264	63	3	1
42	179	43	238	57	3	1

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
43	226	54	192	46	2	1
44	228	54	187	44	5	1
45	134	32	280	67	6	1
46	269	64	145	35	6	1
47	279	66	136	32	5	1
48	250	60	164	39	6	1
49	179	43	237	57	4	1
50	291	69	125	30	4	1
51	275	66	132	31	13	3
52	302	72	108	26	10	2
53	156	37	245	58	19	5
54	175	42	224	53	21	5
55	98	23	298	71	24	6
56	106	25	290	69	24	6
57	380	91	26	6	14	3
58	259	62	147	35	14	3
59	230	55	175	42	15	4
60	46	11	356	85	18	4
61	273	65	133	32	14	3
62	350	83	55	13	15	4
63	309	74	96	23	15	4

Item	Answered Correctly		Did Not Answer Correctly		Did Not Answer	
	N	%	N	%	N	%
64	239	57	164	39	17	4
65	344	82	58	14	18	4
66	340	81	61	15	19	4
67	319	76	79	19	22	5
68	282	67	115	27	23	6
69	271	65	120	29	29	7
70	257	61	134	32	29	7
71	226	54	162	39	32	8
72	231	55	153	36	36	9

$\overline{X}$ = 49.   S.D. = 10.49.

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